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Effects of regulations on technical efficiency of U.S. baitfish and sportfish producers

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ABSTRACT

The stringency of the regulatory environment has been shown to negatively affect the growth of aquaculture. A technical efficiency analysis of baitfish/sportfish production in the United States was performed using a stochastic production frontier model and a jointly estimated maximum-likelihood procedure (Frontier 4.1). Determinants of inefficiency were assessed for their relationship to farm efficiency. Mean technical efficiency for U.S. baitfish and sportfish producers was found to be 77%. Several regulatory variables were found to be significant in explaining the variation in levels of efficiency, including the number of annual renewals of permits and licenses and the amount of manpower required to comply with regulations. Results support the hypothesis that the current regulatory environment in the United States has reduced efficiency and economic competitiveness of baitfish and sportfish producers.

KEYWORDS

Policy analysis; production economics; United States

Introduction

Over the last decade, aquaculture in the United States has experienced an overall decline, driven by rising feed prices, increased pressure from imports, and a complex regulatory environment (Engle and Stone, 2013). A growing body of literature has provided evidence that the regulatory environment can result in excessive costs to aquaculture producers (Abate Nielsen, & Tveterås, 2016; Dresdner & Estay, 2016). More specifically, a recent survey of baitfish and sportfish producers in the United States found that the average annual cost of regulations was \$150,000 per farm that represented costs of \$7400 per ha and 25% of total annual costs (van Senten & Engle, 2017). National industrywide regulatory cost for baitfish and sportfish was estimated to be in excess of \$12 million per year. Moreover, substantial restrictions in access to markets were documented that were attributed directly to the regulatory

environment; more than 60% of respondents from that study reported lost or foregone sales as a result of regulations or regulatory complexity.

The U.S. baitfish and sportfish industry satisfies recreational demand for anglers and pond owners by producing a variety of fish, including golden shiners (*Notemigonus crysoleucas*), fathead minnows (*Pimephales promelas*), goldfish (*Carassius auratus*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), crappie (*Pomoxis sp.*) and other Centrarchid species (Stone & Thomforde, 2001; USDA, 2014). The 2013 U.S. Census of Aquaculture reported 166 baitfish producers and 282 sportfish producers, with sales in excess of \$52 million (USDA, 2014). While farm size is highly variable across the sector, extensive pond production is the primary method of production. This means that climate and season are important factors for production and directly affect supply and demand of baitfish and sportfish in many regions of the United States. Interstate transport of live fish is a common practice within the industry, and necessary to reach wholesalers, retailers, and end users across the country. However, interstate transport requires compliance with various regulations, mostly focused on aquatic animal health. The exact number of enforcement agencies regulating the permitting and licensure of baitfish and sportfish varies by state, as do the number of permits and licenses, and the specific requirements of those permits and licenses. Most states require a permit or license to propagate fish; in some cases, specific permits or licenses are required for specific species of fish. In most cases, a certificate of health is required for fish to be shipped across state lines, or in some cases between watersheds. The major cost of these permits and licenses is not the direct cost of the permits, but rather the manpower involved in maintaining compliance (van Senten & Engle, 2017). Manpower on the farm is tasked with identifying which regulations are relevant in each state, how to obtain those licenses or permits, completing compliance activities to be eligible for those licenses and permits, completing applications for licenses and permits, and filing records of licenses and permits once obtained. Reporting requirements for permits and licenses also vary by state, with some states requiring all parties involved in the process to maintain a copy of the documentation on hand. The number of annual permit and license renewals for baitfish and sportfish producers average 13, as reported by van Senten and Engle (2017); however, individual farms reported as many as 203.

Beyond simply increasing costs for producers, there is reason to suspect that the current regulatory environment may be affecting the efficiency of baitfish and sportfish producers. The study by van Senten and Engle (2017) demonstrated that regulations primarily increased annual fixed costs but because the regulatory environment also restricted access to markets, farmers were not able to increase the scale of their operation to spread the

increased fixed costs over greater volumes of production. Asche and Roll (2013), using a stochastic frontier approach, found that improvements in governmental regulations resulted in more permanent improvements in efficiency of Norwegian salmon producers. These recent studies contrast with work completed more than 23 years ago (Thunberg Adams, & Cichra, 1994) that concluded that financial and marketing barriers were more problematic in the state of Florida than were regulatory barriers. Thunberg et al. (1994) did not consider baitfish and sportfish in their analysis; however, reports show that the regulatory burden in the United States has increased over time (Crews, 2017). However, no quantitative analysis has been found in the literature to quantitatively test whether the regulatory environment does affect technical efficiency on aquaculture farms or which types of regulatory metrics have significant effects.

A number of factors have been identified that affect technical efficiency of agriculture in general. For example, the greater scale and scope of farms in the U.S. Corn Belt were found to increase farm efficiencies and decrease competitiveness of small family farms (Paul, Nehring, Banker, & Somwaru, 2004; Fengxia, Hennessy, Jensen, & Volpe, 2016). Education and outmigration (Sauer, Gorton, & Davidova, 2015) have also been found to reduce technical efficiency, while efficiency-enhancing investments (Mekonnen, Spielman, Fonsah, & Dorfman, 2015) have been found to increase technical efficiency.

More specific to aquaculture, age, experience and education have frequently been found to significantly affect the technical efficiency of aquaculture farms, although whether the effect is positive or negative varied among reviewed studies (Iliyasu et al., 2014). A variety of other variables, such as farm size appear as significant in some studies (Arita & Leung, 2014) but were not significant in others (Iliyasu et al., 2014). In more recent studies, Sandvold (2016) found that older producers were somewhat more efficient at producing salmon smolts in Norway, and water use was found to affect efficiency of catfish and red tilapia production in tanks in Malaysia (Iliyasu & Mohammad, 2015).

A high level of technical efficiency, producing the maximum output for a given level of inputs, is important for farms to be both competitive and profitable (Murova & Chidmi, 2013; Lakner, Brenes-Muñoz, & Brümmer, 2017). Recent research has suggested that the regulatory environment may reduce farm-level competitiveness of aquaculture. For example, based on an analysis of 95 developed and developing countries, Abate et al. (2016) showed that the stringency of environmental regulations was negatively associated with the rate of growth of aquaculture. A number of studies have concluded that the fragmented nature of regulations for aquaculture and the resulting redundancies need to be addressed in developed countries (Engle & Stone, 2013; Kite-Powell, Rubino, & Morehead, 2013; Abate et al., 2016; Engle, 2016;

Knapp & Rubino, 2016). On the other hand, Rahman, Hatha, Selvam, & Thomas (2016) discussed the importance of increasing the stringency and enforcement of regulations in developing countries. For example, numerous studies have shown that weak enforcement systems in countries such as China and Vietnam contribute to continued widespread use of antibiotics that are banned from use in livestock feeds in the U.S. (Broughton & Walker, 2010; Rico et al., 2012, 2013).

It should be noted that concerns related to the regulatory environment in the U.S. and the European Union (EU) do not stem from a desire to eliminate all regulations. Regulations are necessary to internalize production externalities to maximize social welfare. However, there is increasing evidence of inefficiencies in the regulatory environment specifically related to aquaculture that result from redundancy, unnecessary duplication, and overlap (van Senten & Engle, 2017; Osmundsen, Almklov, & Tveterås, 2017).

The effect of regulations on technical efficiency in agriculture generally is not well defined. For example, neither Paul, Johnston, and Frenley (2000) or Yang, Hsiao and Yu (2008) found significant effects from regulations on technical efficiency of sheep and beef farms in New Zealand and swine farms in Taiwan, respectively. On the other hand, van der Vlist, Withagen and Folmer (2007) reported results confirming Porter's hypothesis (1995) that stricter environmental policy resulted in more technically efficient Dutch horticulture farms.

This study contributes to previous technical efficiency studies by estimating the technical efficiency of U.S. baitfish and sportfish producers, with specific attention to whether variables that reflected regulatory compliance on farms had significant effects on baitfish/sportfish production. Specific objectives include: (1) to estimate technical efficiency on U.S. baitfish and sportfish farms; (2) to identify whether there are regulatory variables that contribute significantly to farm efficiencies; and (3) to estimate potential effects on farm efficiencies of streamlined regulatory processes.

This paper proceeds by first describing the survey used to collect data and the variables of interest and then presenting the production and inefficiency functions of the stochastic frontier model used. The empirical specification and sensitivity analysis are then described, followed by results, discussion, and conclusions.

Materials and methods

Data and variables

A survey was conducted in 2015 to capture data on farm production, costs, and the type, nature, and compliance costs of the total set of regulations that

affect U.S. baitfish and sportfish producers (van Senten & Engle, 2017). The survey targeted the 13 major baitfish and sportfish producing states in the U.S.; budget limitations precluded a national survey. This targeted population composed 81% of the total volume of production (USDA, 2014). The survey was conducted as a census; thus, the data reported are population and not sampling data. The survey was designed to capture line-item quantities and costs of farm inputs, farm production volumes and sales, general farm characteristics, and regulatory compliance activities and costs.

Survey reliability was evaluated through the test-retest method and validity through consultations with experts and pre-testing of the survey instrument (Litwin, 1995). The survey responses covered 74% of the national production volume with responses from 34% of the baitfish/sportfish farms. Detailed information on regulations that affected U.S. baitfish/sportfish farms can be found in van Senten and Engle (2017). Survey data were coded and entered into a spreadsheet (Microsoft Excel[®]) prior to transformation for efficiency analysis using Frontier 4.1 (Coelli, 2011).

Since the baitfish/sportfish industry is composed of a variety of species, production systems, and marketing strategies, production data (both inputs and outputs) were recorded in U.S. dollar values. As an example of the variation in the way various baitfish/sportfish farms measured output, some farms measured production by weight (pounds) while others used inches or “head” of fish (individual units). While it is customary for production functions to be expressed in terms of quantities, it is possible to utilize values as a proxy for quantities (Grieco, Li, & Zhang 2016). In this case inputs were sourced from a competitive market where baitfish and sportfish producers are price takers and subject to the same prices for given inputs (Grieco et al., 2016). Thus, value is a proxy for quantity in this analysis. A description of the variables used and their mean values are presented in Table 1.

There were a total of 60 observations (farms) in the dataset, with over 20 production input categories. All data (output and inputs) were transformed to a per-hectare (ha) value and the natural log taken. Stata 11 (StataCorp, 2009) was used to test for homoscedasticity (RV plot and Breusch-Pagan test), multicollinearity (VIF test), model specification (Lowess test), and normality (Kdensity, Pnorm, Qnorm, and Shapiro–Wilk test).

Stochastic Frontier Model

The stochastic frontier production model (Aigner, Lovell, & Schmidt, 1977) can be expressed as:

$$\ln Y_i = f(\beta, X_i) + \varepsilon \quad (1)$$

Table 1. Definition of variables and average values.

Parameter	Symbol/Coefficient	Description	Average value
<i>Production function</i>			
Sales	γ	Total sales (output)	\$878,136
Feed	β_1	Feed used in production	\$84,413
Amm	β_2	Fertilizer, herbicides, pesticides, disinfectant, and other chemicals (amendments)	\$28,648
Rep	β_3	Repairs and maintenance of facilities, equipment, and infrastructure	\$25,000
Ins	β_4 / δ_6	Insurance for the farm business	\$31,321
Labor	β_5	Total labor for the farm production (minus the cost of manpower for regulatory compliance)	\$222,709
Other	β_6	Other production activities: pumping water, electricity, interest on loans, office expenses	\$54,218
RegCost	β_7	Total cost of regulatory compliance	\$148,554
<i>Inefficiency function</i>			
<i>Regulatory variables</i>			
Renew	δ_{10}	Number of annual permit/license renewals	16.11
ChangeR	δ_3	Changes due to regulations	\$16,008
Fhealth	δ_4	Fish health activities	\$7,250
Ins	β_4 / δ_6	Insurance for the farm business	\$31,321
Lost	δ_2	Lost/foregone sales due to regulations	\$85,039
ManR	δ_5	Manpower to comply with regulations	\$15,948
Nstate	δ_{11}	Number of state regulations	7.12
Nfed	δ_{12}	Number of federal regulations	1.18
Nship	δ_9	Number of states shipped to	9.70
<i>Farm characteristic variables</i>			
Size	δ_1	Farm size (ha)	156.36
Bait	δ_7	Raising baitfish only (dummy variable)	0.25
Sport	δ_8	Raising sportfish only (dummy variable)	0.38
Gregion	δ_{13}	Farm is located in the Great Lakes region (dummy variable)	0.40
Sregion	δ_{14}	Farm is located in the Southeast region (dummy variable)	0.15

where $\ln Y_i$ represents the stochastic frontier for observation i , β is the parameter estimate of X_i , X_i represents the explanatory variable, i , (input i), and ε is the error term. The error term (ε) consists of two components; V_i

a firm specific white-noise stochastic error and U_i the firm specific inefficiency (Asche & Roll, 2013). The frontier production function represents the case where there is no inefficiency in the model ($U_i = 0$) (Coelli, Rao, O'Donnell, & Battese, 2005). The gap between the stochastic frontier and a firm's observed production output, then, represents that specific firm's inefficiency. Technical efficiency is commonly represented as a ratio (Coelli et al., 2005), where 1 represents complete efficiency and 0 complete inefficiency. Expressed in terms of inputs X_i and firm specific output Y_i as (Murova & Chidmi, 2013); technical efficiency is:

$$TE = \frac{Y_i}{f(\beta X_i)} = \frac{f(\beta X_i - U_i)}{f(\beta X_i)} \quad (2)$$

Assuming a half-normal distribution of the error term allows for a more simplified approach to the determinants of inefficiency (Asche & Roll, 2013). A separate function represents the inefficiency of each firm (σ^2), as a function of explanatory variables Z_i , which may be the same as X_i from the stochastic frontier function (Asche & Roll, 2013):

$$\sigma_i^2 = \exp(Z_i, W) \quad (3)$$

where W is a vector of those same explanatory variables (Z_i).

Battese and Coelli (1995) argued that two-stage estimation of efficiency was inconsistent in its assumption of the independence of inefficiency effects. Therefore, they developed a model to perform a joint estimation of the firm-level efficiencies and regress those predicted efficiencies over firm-specific variables (Coelli, 2011):

$$Y_{it} = \beta X_{it} + (V_{it} - U_{it}) \quad (4)$$

$$i = 1, \dots, N, \quad t = 1, \dots, T$$

where Y_{it} is the dependent variable, X_{it} the explanatory variable, β is the parameter estimate of X_{it} explanatory variable, V_{it} are random variables assumed to be independent and identically distributed $N(0, \sigma_v^2)$, and U_{it} are non-negative random variables assumed to account for technical inefficiency (Coelli, 2011). The Battese and Coelli specification also assumes that U_{it} is independently distributed as truncations at zero of $N(m_{it}, \sigma_u^2)$, where (Coelli, 2011):

$$m_{it} = z_{it} \delta \quad (5)$$

where Z_{it} is a vector of the variables influencing inefficiency and δ is a vector of the parameters to be estimated (Coelli, 2011). Through replacing σ_v^2 and σ_u^2 :

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \text{ and } \gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2) \quad (6)$$

this model can be estimated through a maximum-likelihood procedure (Coelli, 2011). The Frontier 4.1 program utilizes a three-step estimation

procedure to obtain maximum likelihood estimates of the parameters in the stochastic frontier production function as follows (Coelli, 2011):

1. an ordinary least squares (OLS) estimate of the function is performed where, with the exception of the intercept, all parameter estimates (β) are unbiased;
2. a grid search of γ with parameters (β) set to the OLS estimates; and
3. an iterative maximization procedure using first-order partial derivatives to obtain final maximum likelihood estimates (Davidon–Fletcher–Powell Quasi-Newton method).

Empirical specification

A number of production variables were consolidated to correct for issues of multicollinearity. For example, fertilizer, herbicides, disinfectants, and chemicals were grouped into a variable named “amendments.” Similarly, on-farm energy inputs (electricity and pumping water), fuel inputs, and other miscellaneous inputs were grouped into an “other” variable. The final stochastic frontier production model was:

$$\begin{aligned} \ln Sales = & \beta_0 + \beta_1 \ln Feed_i + \beta_2 \ln Amm_i + \beta_3 Rep_i \\ & + \beta_4 \ln Ins_i + \beta_5 \ln Labor_i + \beta_6 \ln Other_i \\ & + \beta_7 \ln RegCost_i + (V_i - U_i) \end{aligned} \quad (7)$$

where β_i is the parameter estimate of explanatory variables of feed ($\ln Feed_i$), amendments ($\ln Amm_i$), repairs and maintenance ($\ln Rep_i$), insurance ($\ln Ins_i$), labor ($\ln Labor_i$), other miscellaneous inputs ($\ln Other_i$), and regulatory costs ($\ln RegCost_i$) expressed as natural logs. V_i are random variables assumed to be independent and identically distributed $N(0, \sigma_v^2)$, and U_i are non-negative random variables assumed to account for technical inefficiency (Coelli, 2011). A likelihood ratio test value of 59 exceeded the upper bound Wald criteria for joint testing of the equality and inequality restrictions at the 5% level (Kodde & Palm, 1986), and therefore the null hypothesis of a trans-log model over a Cobb-Douglas model was rejected; the Cobb-Douglas specification was used for the analysis.

The inefficiency function focused on descriptive and regulatory cost variables obtained from the survey. These regulatory variables were selected based on findings from van Senten and Engle (2017) who identified manpower to comply with regulations, fish health testing, changes due to regulations, and lost and foregone sales as substantial elements of the regulatory compliance cost on farms. Lost and foregone sales contributed the largest portion of regulatory cost (57%), followed by changes due to regulations (22%), manpower to comply with regulations (11%), and fish health testing costs (5%). It should be noted that the costs of farm-level changes due to

Table 2. Hypothesis testing for stochastic frontier and inefficiency parameters.

Null hypothesis	Log likelihood statistic	Critical value	Decision
$H_0: \gamma = \delta_0 = \delta_1 = \dots = \delta_{14} = 0$	25.22	5.14 –24.384	Rejected
$H_0: \gamma = 0$	39.49	5.14–32.07	Rejected
$H_0: \delta_0 = \delta_1 = \dots = \delta_{14} = 0$	59.18	24.99	Rejected
$H_0: \delta_0 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_9 = \delta_{10} = \delta_{11} = \delta_{12} = 0$	58.44	16.92	Rejected
$H_0: \delta_0 = \delta_2 = \delta_3 = 0$	43.05	7.82	Rejected
$H_0: \delta_0 = \delta_5 = \delta_{10} = 0$	58.33	7.82	Rejected
$H_0: \beta_1 + \beta_2 = + \dots + \beta_7 = 1$	–6547.85	3.84	Not rejected

regulations did not include permit/license renewals or manpower; only the costs of implementing the change, to avoid double counting regulatory-induced costs. While the direct cost of permits and licenses may only have accounted for 1% of total regulatory costs on average, the relationship between the number of annual license and permit renewals (in excess of 100 in some cases) and the manpower compliance costs of producers was also noted. Hence, these regulatory variables were believed to be likely contributors to inefficiency on farms and were included in the inefficiency function. In addition to these variables, dummy variables for the type of fish raised on farms and the region in which farms were located were added to the function. The function as entered into Frontier 4.1 was specified as:

$$\begin{aligned}
 m_i = & \delta_0 + \delta_1 \text{Size}_i + \delta_2 \text{Lost}_i + \delta_3 \text{ChangeR}_i + \delta_4 \text{FHealth}_i \\
 & + \delta_5 \text{ManR}_i + \delta_6 \text{Ins}_i + \delta_7 \text{Bait}_i + \delta_8 \text{Sport}_i + \delta_9 \text{NShip}_i + \delta_{10} \text{Renew}_i \\
 & + \delta_{11} \text{NState}_i + \delta_{12} \text{NFed}_i + \delta_{13} \text{GLRegion}_i + \delta_{14} \text{SeRegion}_i + \varepsilon_i
 \end{aligned}
 \tag{8}$$

where m_i is the mean of the non-negative random variables (U_i) assumed to account for technical inefficiency, δ_i is the parameter estimate of farm size (Size_i), lost/foregone sales (Lost_i), changes due to regulation (ChangeR_i), fish health activities (FHealth_i), manpower cost of compliance (ManR_i), insurance for the farm (Ins_i), dummy variable for raising baitfish only (Bait_i), dummy variable for raising sportfish only (Sport_i), number of states shipped to (NShip_i), number of annual permit/license renewals (Renew_i), number of state regulations (NState_i), number of federal regulations (NFed_i), dummy variable for the Great Lakes region (GLRegion_i), dummy variable for the Southeast region (SeRegion_i), and ε_i is the error term. The base scenario modelled was for a farm raising both baitfish and sportfish in the South Central region. The technical efficiency of the i^{th} sample farm (TE_i) is obtained as $TE_i = \exp(-U_i)$.

Hypothesis testing

Three hypotheses related to the validity of the estimates developed were tested with a generalized likelihood ratio test (Hassan & Ahmad, 2005)

Table 3. Average efficiency scores by state/grouping.

State/Grouping	Average efficiency score	Min	Max
Alabama	0.929	0.833	0.967
Arkansas	0.822	0.431	0.955
New York	0.795	0.621	0.939
North Carolina	0.927	0.905	0.959
Ohio	0.553	0.008	0.934
Pennsylvania	0.462	0.181	0.765
Wisconsin	0.925	0.909	0.955
Other States*	0.865	0.596	0.961
All Observations	0.766	0.008	0.967

*Florida, Illinois, Kansas, and Texas are included under "Other States".

(Table 2). The first tested for the absence of inefficiency effects from the model as follows:

$$H_0: \gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = \delta_8 = \delta_9 = \delta_{10} = \delta_{11} = \delta_{12} = \delta_{13} = \delta_{14} = 0.$$

Secondly, the inefficiency effects of the model were tested for not being stochastic as follows:

$$H_0: \gamma = 0.$$

The third hypothesis tested was to determine if the 14 variables used in the inefficiency equation (11), had a significant effect on the inefficiency, with the following null hypothesis:

$$H_0: \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = \delta_8 = \delta_9 = \delta_{10} = \delta_{11} = \delta_{12} = \delta_{13} = \delta_{14} = 0.$$

A hypothesis of whether regulatory variables in the inefficiency function contributed to technical efficiency of the model was tested with the following null hypothesis:

$$H_0: \delta_0 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_9 = \delta_{10} = \delta_{11} = \delta_{12} = 0.$$

Separate hypothesis tests were performed on the effect of the regulatory variables that were significant on technical efficiency with the following null hypotheses:

$$H_0: \delta_0 = \delta_5 = \delta_{10} = 0.$$

Positive coefficients (number of annual permit/license renewals and manpower to comply with regulations)

$$H_0: \delta_0 = \delta_2 = \delta_3 = 0.$$

Negative coefficients (changes due to regulations and lost/foregone sales)

Constant returns to scale were tested with the following hypothesis:

$$H_0: \beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5 + \beta_6 + \beta_7 = 1.$$

Results

Technical efficiency estimates were obtained for all 60 farms, with an average efficiency of 77% across all participants (Table 3). In order to preserve confidentiality, efficiency estimates presented in Table 3 are summarized by

Table 4. Parameter estimates for jointly estimated stochastic frontier model.

Parameter	Coefficient estimate	Standard error	T-ratio	Significant ($p < 0.05$)
<i>Production function</i>				
Intercept (β_0)	3.166	0.719	4.403	
Amendments	-0.126	0.061	-2.048	*
Repairs and maintenance	0.333	0.086	3.893	*
Labor	0.211	0.088	2.406	*
Feed	0.174	0.140	1.245	
Insurance	0.178	0.102	1.756	
Regulatory cost	0.018	0.060	0.296	
Other	0.153	0.043	3.547	*
<i>Inefficiency function</i>				
Intercept (δ_0)	-3.216	0.856	-3.756	
<i>Regulatory variables</i>				
Annual renewals of permits/licenses	0.007	0.003	2.339	*
Changes due to regulation	-0.187	0.057	-3.289	*
Fish health regulations	-0.093	0.066	-1.414	
Insurance	0.640	0.176	3.635	*
Lost/foregone sales	-0.099	0.046	-2.178	*
Manpower to comply with regulations	0.220	0.082	2.669	*
Number of federal regulations	-0.061	0.095	-0.643	
Number of state regulations	-0.043	0.032	-1.334	
Number of states shipped to	-0.005	0.017	-0.281	
<i>Farm characteristic variables</i>				
Farm size	0.002	0.001	1.918	
Baitfish only (dummy)	-0.109	0.557	-0.196	
Sportfish only (dummy)	-0.753	0.382	-1.969	*
Great Lakes region	-0.121	0.515	-0.235	
Southeast region	-1.658	0.924	-1.795	
σ^2	0.255	0.070	3.647	
γ	0.365	0.189	1.930	

state (with Florida, Illinois, Kansas, and Texas included under “Other States”).

The null hypothesis for the first hypothesis test related to the validity of the estimates developed ($H_0: \gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = \delta_8 = \delta_9 = \delta_{10} = \delta_{11} = \delta_{12} = \delta_{13} = \delta_{14} = 0$) was rejected (test statistic of 25.22; critical value range of 5.14 to 24.38), indicating that the model contains inefficiency effects. The null hypothesis for the second null hypothesis related to the validity of estimates developed ($H_0: \gamma = 0$) was also rejected (test statistic of 39.49 exceeding the critical value range of 5.14 to 32.07). Therefore, the technical inefficiency effects of the model are understood to be random (Hassan & Ahmad, 2005). The third hypothesis tested related to the validity of the estimates developed ($H_0: \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = \delta_8 = \delta_9 = \delta_{10} = \delta_{11} = \delta_{12} = \delta_{13} = \delta_{14} = 0$) was rejected (exceeded the critical value of 24.99). Thus, the 14 variables specified were found to have an effect on technical inefficiency.

The parameter estimates for each variable from the maximum-likelihood estimation procedure are listed in Table 4. In the stochastic production function (8) estimated, the β coefficients reveal that “amendments”, “repairs and maintenance”, “labor”, and “other” (included costs to pump water, electricity, and interest expenses on loans), variables were significant (asymptotic absolute value t -ratio > 1.96). The negative coefficient for the

“amendments” variable indicated that production output decreased as amendment usage increased. Variables denoting feed, insurance, and regulatory costs were not significant.

In the inefficiency function, the following variables were significant (asymptotic absolute value t -ratio > 1.96): “permit/license renewals”, “changes due to regulations”, “insurance”, “lost/foregone sales”, and “manpower to comply with regulations”. Of the farm characteristic variables, only the dummy variable for “Sportfish” was significant.

The hypothesis of whether regulatory variables in the inefficiency function contributed to technical efficiency of the model was rejected (test statistic of 58.44 exceeded the critical value of 16.92), and the regulatory variables specified were found to contribute to technical inefficiency in the model. Both null hypotheses tested on the effect of the regulatory variables that were significant on technical efficiency were rejected, suggesting that these respective variables (positive coefficients and negative coefficients) did have an effect on technical inefficiency of baitfish and sportfish producers. The null hypothesis for constant returns to scale was not rejected (test statistic of $-6,547.85$, lower than the critical value of 3.84), indicating that the model as specified exhibited constant returns to scale.

Discussion

Production function

The base scenario modelled by the estimation was for a farm raising both baitfish and sportfish in the U.S. South Central region; with dummy variables accounting for farms that raised only baitfish or only sportfish, and farms located in the Great Lakes region and Southeast region. Results of the stochastic production frontier estimation for U.S. baitfish/sportfish demonstrated that feed was not a significant input for baitfish and sportfish producers in this study in contrast with foodfish production (Lacewell, Nichols, & Jambers, 1973; Nerrie, Engle, Hatch, & Smitherman, 1990; Losinger, Dasgupta, Engle, & Wagner, 2007; Engle, 2010). Baitfish and sportfish producers more commonly use fertilizers to promote algal blooms and natural food with supplemental, rather than intensive feeding of commercial diets. In some instances, producers rearing both baitfish and sportfish have used surplus baitfish as forage to supplement feeding of sportfish. Indeed, the “amendments” variable that included fertilizer, was significant. The negative coefficient on this variable may reflect the need to fertilize at higher rates in ponds with water with high calcium hardness (Brunson, Hargreaves, & Stone, 2000), typical of the quality of water found on many baitfish/sportfish farms in Arkansas, where the greatest amount of baitfish/sportfish are raised in the U.S. The increasing difficulty of controlling

problematic aquatic vegetation in older ponds, such as those used for baitfish and sportfish production may result in weedy ponds that tend to have less phytoplankton and zooplankton for baitfish and sportfish to feed on (Jones et al., 2016).

The variables “repairs and maintenance”, “labor”, and “other” inputs of production were also significant in the production function, with positive coefficients. Thus, as the value of repairs and maintenance and labor increased, so did production output. This result aligns well with common knowledge of the management of many aquaculture businesses, in which labor, fuel, and costs to pump water, among others are important costs of aquaculture businesses. Given the relatively high level of fixed costs as a percentage of total annual costs in baitfish and sportfish production, repair and maintenance costs would be expected to be relatively higher to maintain intermediate and long-term assets such as equipment, buildings, and pond infrastructure. Labor is a major cost of production in baitfish/sportfish (Stone, Kelly, & Roy, 2016) as is the combined costs of pumping, electricity, and interest costs included in the “other” category.

The regulatory cost variable was not found to be significant in the production function, signifying that the cost of regulations did not significantly explain the quantity of baitfish and sportfish produced. While the overall cost of compliance was found to be a major economic burden on producers, van Senten and Engle (2017) demonstrated that 60% of the total regulatory cost was the opportunity cost of lost or foregone sales. The direct cost of regulations, as measured in the survey, is composed of the direct costs and fees of the permits and licenses. The costs of the permits and licenses required for U.S. baitfish/sportfish was found to compose only 1% of the total regulatory cost. A similar finding, that the cost of permits and licenses composed only a very small part of the total farm-level cost of regulations, was previously reported by Hurley and Noel (2006) for California agricultural producers.

Inefficiency function

In the inefficiency function, several regulatory variables significantly contributed to farm inefficiency, including: (1) the number of permit/license renewals each year; (2) manpower to comply with regulations; (3) changes due to regulations; and (4) lost/foregone sales. The insurance variable, although not a regulatory variable, was also significant. Other regulatory variables such as the numbers of state and federal regulations, the number of states shipped to, farm size, and fish health regulations were not found to contribute significantly to farm efficiency.

The positive coefficient for the “number of annual permit and license renewals” in the inefficiency equation, was significant. Survey respondents reported a high number of annual renewals of permits and licenses. One-third of respondents reported between 10 and 203 annual renewals a year. While the majority of these permits and licenses (90%) were obtained from state agencies, approximately 33% of the state regulations had been developed to enforce federal statutes. Respondents reported being required to annually renew multiple permits from multiple agencies, sometimes within the same states, that request the same information. The significance of the number of annual renewals indicates the complexity of the regulatory environment.

Manpower spent to comply with regulations was also found to be a significant determinant of inefficiency on farms. Thus, as more manpower was used to comply with regulations, the technical efficiency of the farm was reduced. This is likely a reflection of the fact that diverting manpower towards regulatory compliance activities reduces the time available for productivity-enhancing innovations or to develop new markets and results in a reduction in production output.

Other studies have reported negative effects on U.S. aquaculture farms that result from the time and manpower required to comply with the complexity created by the total set of regulations with which aquaculture businesses contend (Engle & Stone, 2013; Kite-Powell et al., 2013). Often, it is the farm owner or manager who must spend time to ensure that the business is fully compliant with provisions, monitoring, and compliance with all required permits and licenses. The overlapping and redundant nature of many of the state regulations faced by baitfish/sportfish producers in the U.S., who ship most of their product to other states, has been cited in existing literature as a major part of the regulatory burden on aquaculture businesses in the U.S. (Engle & Stone, 2013; Kite-Powell et al., 2013). As revealed by the data in this study, significant manpower is required at the farm level to attend to these overlapping and redundant regulatory requirements, which very often have different reporting formats and deadlines. In other types of agriculture, labor productivity was found to be a significant determinant of technical efficiency, for example, in the Greek food and beverage market (Rezitis & Kalantzi, 2016). Hurley (2004) reported a 40% increase in manpower time spent by agricultural producers in California on regulatory compliance, with the manpower costs constituting the greatest cost of regulatory compliance. In the data used for the present baitfish and sportfish study, the cost of manpower to comply with regulations was only 11% of the total regulatory cost (van Senten & Engle, 2017); but it was noted that this value was likely underestimated. Producer respondents in the survey did not keep records of the time spent on every telephone call or contact to request application forms, to identify changes in regulations

from the previous year, or in a number of cases, to identify the appropriate individual in charge of the permit for that year.

The variable “insurance” was also found to be a significant determinant of inefficiency. The survey results documented relatively high costs associated with a variety of insurance products on baitfish and sportfish farms, which is why insurance was included as a variable in the analysis even though it was not a regulatory cost, nor a requirement for producers. Insurance is a management option to reduce various types of financial risks in a farm business. The significance of insurance in the model likely reflects attempts by farmers to manage the risk associated with baitfish and sportfish businesses and may reflect a greater degree of risk associated with baitfish/sportfish production as compared to foodfish production.

Lost or foregone sales were significant but with a negative sign on the coefficient. While a literal interpretation would indicate that lost sales increased farm efficiency, the data show that a number of respondents reported few or no foregone sales; moreover, farms reporting higher quantities of foregone sales, were more efficient on average. It appears that farms that operated at high levels of technical efficiency also had better records, including those of sales that had been lost due to regulatory changes or increased complexities. The importance of foregone sales as an unintended consequence of regulatory compliance requirements was also identified by Dresdner and Estay (2016) in their assessment of potential effects on the Chilean salmon industry of various biosecurity measures proposed in response to disease outbreaks. To avoid substantial foregone sales that would have been based on production limits to Chilean salmon farms, Dresdner and Estay (2016) proposed an approach that would result in estimates of optimal levels of biosecurity regulation, given both the need for disease control and the need to avoid excessively costly levels of production limits that would restrict sales of salmon.

The cost of changes on the farm due to regulations also had a negative coefficient, implying that increased costs of the changes improved farm efficiencies. Farms that reported the highest costs for changes due to regulations were also those that scored very high on estimated technical efficiency. Those were likely also the farms with more comprehensive records, and were those that were able to remain in business because they incurred the expense to comply with regulatory changes. Those farms had a better understanding of how regulatory changes had resulted in infrastructure and management changes in their business and how this added additional costs. Management changes reported to comply with regulations tended to include hiring additional personnel for record-keeping and hiring additional drivers for more numerous, smaller, but more expensive trucks. Such changes all increased costs, but larger farms that have stayed in business were those that made the

changes. Smaller farms unable to make such changes likely exited the industry. van Senten and Engle (2017) showed that 23% of the total farm costs of regulations were due to changes made to be in compliance.

Farm size was not found to be significant in the inefficiency equation. In other studies of the technical efficiency of aquaculture, farm size generally was not found to explain economic efficiencies (Iliyasu et al., 2014). This was also true in analysis across counties in a specific country (Tan et al., 2011) or across countries (Dey, Paraguas et al., 2005; Dey, Rab et al., 2005), although results are variable. In U.S. baitfish/sportfish production, 29% of small-sized farms exited the industry between 2005 and 2013 (USDA, 2014). van Senten and Engle (2017) attributed this decrease in part to the substantially greater costs/ha imposed by regulations on smaller, as compared to larger, farms.

Quantitative identification of regulatory variables that were significant determinants of inefficiency, confirms that suggested by the descriptive data discussed by van Senten and Engle (2017) in their summary of regulatory costs on U.S. producers of baitfish and sportfish. Nearly, one-third (30%) of survey respondents indicated that their top challenges (first or second) were related to issues related to regulatory compliance. The current study affirms that several components of regulatory compliance have increased farm-level inefficiencies for U.S. baitfish and sportfish producers.

The problem that has emerged over the years is not necessarily the laws and regulations themselves, but how the permits are written and enforced. Osmundsen et al., (2017) referred to the dynamic nature of aquaculture technologies that poses problems for regulators who frequently have little formal training in aquaculture nor the means to remain current with its rapidly evolving technologies and management practices. Osmundsen et al., (2017) called for a more adaptive regulatory system that would avoid restricting new productivity-enhancing technologies on aquaculture farms. Abate, Nielsen and Nielsen (2018) discussed the effects of inter-agency rivalry, ideological perspectives of regulatory personnel, and the subsequent effects on the regulatory environment for industries such as aquaculture.

Further analysis investigating effects of regulatory variables on technical efficiency revealed that decreasing the number of permits/licenses would result in an increase in efficiency on farms (Table 5). Similarly, a decrease in the cost of manpower for compliance would result in increased efficiency, providing further evidence for the idea that the diversion of manpower to compliance tasks has a negative effect on production.

Conclusions

Regulatory variables in the inefficiency function were found to be significant determinants of farm inefficiency on U.S. baitfish/sportfish farms,

Table 5. Sensitivity of technical efficiency score to the changes in number of permits and manpower costs.

Variable (X)	X level	Decrease in X	<i>U</i>	<i>TE</i>
No. of permits				
Now	16.000	0.000	0.267	0.766
10% reduction	14.400	1.600	0.255	0.775
20% reduction	12.800	3.200	0.244	0.783
30% reduction	11.200	4.800	0.233	0.792
40% reduction	9.600	6.400	0.222	0.801
50% reduction	8.000	8.000	0.211	0.810
Manpower cost (in natural logarithms)				
Now	9.677	0.000	0.267	0.766
10% reduction*	9.572	0.105	0.243	0.784
20% reduction*	9.454	0.118	0.241	0.786
30% reduction*	9.320	0.134	0.237	0.789
40% reduction*	9.166	0.154	0.233	0.792
50% reduction*	8.984	0.182	0.226	0.797

*Represents reduction in absolute values of manpower cost.

affirming that the U.S. regulatory environment has affected the competitiveness of baitfish and sportfish producers by reducing farm-level efficiency. The significant effect of variables such as the number of annual permit/license renewals and manpower to comply with regulations demonstrates that the time farmers spend attempting to navigate a complex and convoluted business environment takes time away from productivity-enhancing innovations and new market development. The farmers who participated in the study did not argue that there should be no regulations; in fact, several pointed out the need for regulations to maintain and protect the social quality of life they desire and the natural systems they not only rely on, but personally value and enjoy. However, this study, combined with the descriptive results reported by van Senten and Engle (2017) point to a regulatory environment that is characterized by redundancy across agencies and in reporting of compliance. The determinants of inefficiency identified in this analysis demonstrate the excessive time burden on family businesses whose owners are attempting to comply with the law, and, as a result, are operating less efficiently than possible.

There clearly is a strong need to identify effective and practical ways to streamline monitoring and compliance reporting activities across local, state, and federal agencies to reduce the time burden and inefficiencies that are introduced at the farm level and for prompt notification to farmers of deadlines for renewals and of changes in the regulatory requirements. This study demonstrates that the time burden resulting from compliance activities for producers is significant and that poor communication between and from agencies results in additional, sometimes unexpected, costs at the farm level. Specifically, it identifies areas of indirect regulatory cost that have had a negative effect on farm technical efficiency. Study findings suggest that reducing the time burden at the farm level, resulting from

frequent permit and license renewals and duplicative reporting requirements, as well as reducing unexpected changes at the farm level, resulting from poor communication and poorly accessible information, could improve farm efficiency. One possible solution would be for policy makers to work closely with industry to understand how some regulations result in unintended consequences at the farm level. Improved communication and information sharing between agencies may also help to reduce the manpower required for reporting compliance at the farm level. Likewise, development of uniform reporting standards and forms, and easily accessible information regarding regulations and compliance requirements could also aid in reducing the time burden for producers. In the end, both regulators and producers share the common goal of achieving compliance; working together to identify solutions that are feasible, satisfy both sets of needs, and reduce complexity benefits all parties involved.

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