FACTORS AFFECTING U.S. AQUACULTURISTS' INTENDED ACTIONS TO EXPAND PRODUCTION CAPACITY ABROAD

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ABSTRACT

This paper examines the relationship between U.S. aquaculturists' intended actions to expand production capacity abroad and the factors influencing their choices. These factors include aquaculturists' perceptions of market conditions; regulatory climate; property rights; government leadership; and the comparative advantages of U.S. aquaculture, as well as the demographic characteristics of aquaculturists and their farms. Primary data were collected via an original online survey. Both multinomial probit and probit models identify the factors affecting aquaculturists' intended actions to expand abroad. The results indicate that large-scale, non-shellfish (e.g., finfish, salmon, or shrimp), less-educated, marine aquaculturists with high expectations about seafood demand during the next three years; who think U.S. permit and environmental regulations are strict; that aquaculture leases should be transferable; and that the U.S.A. has comparative advantages in skilled labor availability and access to the domestic markets, are more likely to expand their operations abroad. The results provide guidance for U.S. policy makers to help retain aquaculture entrepreneurs and investors domestically.

Keywords: US aquaculture producers, expansion production, factors, probit model

INTRODUCTION

Aquaculture has played a significant role in filling the gap between the stabilized wild-caught seafood supply and the increasing seafood demand (FAO 2007, Marine Aquaculture Task Force 2007). In the past three decades, global aquaculture has experienced tremendous growth worldwide, with an average annual growth rate of nearly 8% between 1978 and 2007 (FAO 2009). Anderson (1995) defined aquaculture as "the single most exciting development in the animal protein industry since the domestication of cattle" (p. 1319). Following the green revolution in terrestrial land, aquaculture has triggered a blue revolution in the sea (The *Economist*, 2003; Asche, Guttormsen, and Tveteras, 2008).

However, U.S. aquaculture has not kept pace with the world aquaculture industry. In 2007, the total U.S. aquaculture production was 526,281 metric tonnes with a value of $944.5 million, accounting for less than 1% of the world aquaculture production (FAO 2009). This was not always the case. During 1978-1987, the U.S. aquaculture industry developed quickly. With the rapid growth of freshwater aquaculture, U.S. aquaculture took off with an annual growth rate of 9.2%; higher than that of the world (7.8%) (FAO 2009). However, this rate of growth has not been observed since. This was mainly because U.S. freshwater aquaculture decelerated substantially and U.S. marine aquaculture was stagnant. Even though U.S. marine aquaculture seemed to improve with an annual growth rate of 3.4% from 1998 to 2007, it is still lower than that of the world (5.6%) (FAO 2009).

Globally, aquaculture's share of the seafood supply is increasing relative to the capture fishery, but a similar trend is not observed in the U.S.A. In 2007, world aquaculture production was 65.2 million metric tonnes, contributing 41.7% of the global seafood production (156.4 million metric tonnes) (FAO 2009). In contrast, U.S. wild fisheries still dominated U.S. seafood production with a share of over 90% (FAO 2009). The importance of aquaculture as a seafood source is not manifested in the U.S. seafood production figures, but it is evident in U.S. consumption statistics. Species which are primarily farmed are displacing wild-caught species in the top ten species consumed in the U.S.A. (National Fisheries Institute,

2009). Catfish is the only U.S. domestically farmed species on the top ten. U.S. aquaculture is not playing a significant role in satisfying domestic seafood demand.

What are the reasons for slow development of aquaculture in the U.S.A.? Previous research indicates that a strict regulatory environment, cost uncertainties, weak government advocacy, strong local decision-making authority, large number of coastal land owners' opposition, environmental constraints, and poor marketing (Lockwood, 2001b; Anderson and Bettencourt, 1993; National Research Council, 1992) have contributed to the slow development of the U.S. aquaculture industry. Nevertheless, aquaculture is a profit-oriented business and investors will go where there is an expectation to make profit. The opportunities will pass while waiting for the enabling institutions to manifest these conditions.

Globalization and economic integration creates opportunities for firms to move outside the U.S.A. (Anderson 2003). Integration of economies is characterized by a significant decrease of transportation cost, combined with a high degree of specialization, spillover effects of knowledge, and communication technologies (Peri 2002; Tveteras 2002). Driven by the international seafood trade and efforts to take advantage of economies of scale, the aquaculture industry is moving towards increased consolidation (Anderson 2003). It includes not only vertical and horizontal integration within the country, but also integration across countries to take advantage of productive inputs such as inexpensive labor, easy entry, and low regulation compliance cost.

In 1992 the National Research Council posed the question, "Given the existence of growing seafood demand and the capacity of U.S. science and engineering to design and operate advanced systems, why has U.S. aquaculture lagged behind other countries in productivity and profitability?" (NRC, 1992 p.14) This question is still relevant today. Many aquaculture opponents focus on the ecological and environmental impacts of aquaculture, but few people pay attention to the economic effects and health benefits of conducting aquaculture domestically (Jin, Kite-Powell, and Hoagland, 2005). No previous research has addressed the issues of why the U.S.A. has not established a major seafood producing industry after investing millions of dollars through national research labs and universities on aquaculture for the past three decades. This paper uses primary survey data to examine the factors affecting U.S. aquaculturists' intended action to expand/invest production capacity abroad, contributing to the slow growth of U.S. production. It provides statistical evidence for some of the arguments mentioned above.

EMPIRICAL MODEL OF THE DECISION TO INCREASE PRODUCTION CAPACITY

An aquaculturist's target is to maximize profit. Assuming individual aquaculturist, *i*, makes a decision as to whether they will expand production capacity, the expected profit of expanding can be expressed as:

$$\boldsymbol{\pi_{ij}} = \boldsymbol{x'_{ij}\beta_{ij}} + \boldsymbol{\varepsilon_{ij}}, \quad (1)$$

where, $\boldsymbol{\pi_{ij}}$ is the expected profit achieved by aquaculturist *i* by choosing one particular action *j*. $\boldsymbol{\pi_{ij}}$ takes values of 0, 1, and 2, representing aquaculturists' decision of 'no,' 'yes,' and 'uncertain' regarding expansion abroad. $\boldsymbol{x_{ij}}$ denotes the factors affecting aquaculturists' intended actions to expand operations, such as market expectations, perceptions of the regulatory climate, farm size, farmed species, farming environment, and aquaculturists' demographic characteristics. $\boldsymbol{\beta_{ij}}$ is the coefficient of the parameter. $\boldsymbol{\varepsilon_{ij}}$ is the random component of profit associated with the choice of actions *j* and aquaculturist *i*. If the random component follows the normal distribution, it is a (multinomial) probit model when there are (more than) two alternative choices. Aquaculturist *i* will take action *j* when:

$$\text{Prob[choice j]} = \text{Prob}[\pi_{ij} > \pi_{ik}, k = 1, \dots, \text{J}, \text{j} \neq \text{k}. \quad (2)$$

The probability of this occurrence is (Greene 2002):

$$\text{Prob[choice j]} = \text{Prob}\left[\varepsilon_{ij} - \varepsilon_{ik} > x'_{ik}\beta_{ik} - x'_{ij}\beta_{ij}\right] = \Phi(X'\beta), \quad (3)$$

where Φ is the cumulative distribution function (CDF) of the standard normal. Computing probabilities from the multivariate normal distribution are involved to evaluate the likelihood function.

In this study, four models are used to examine the relationship between aquaculturists' intended action, *j*, and factors influencing their intended actions to expand production capacity abroad. Models 1 and 2 employ a multinomial probit model on the belief that aquaculturists who choose 'uncertain' indicate they are considering expanding abroad, and thus it is important to understand the potential influencing factors. Models 3 and 4 use a probit model to concentrate on the differences between the definite answers 'yes' and 'no.'

SURVEY DESGIN

Data used in this analysis are from an original online survey about U.S. aquaculture stakeholders' perceptions and actions conducted between September 2008 and March 2009. The survey was composed of a wide variety of questions, including those regarding aquaculture stakeholders' roles and expertise; their knowledge of aquaculture and its policies; their expectations about the future of the aquaculture sector; their perceptions about regulatory stringency; and their intended actions for the next three years regarding operation expansion.

Respondents include aquaculturists, government officials, researchers/consultants, environmental NGOs, fishermen, and other post-harvest business professionals (*e.g.*, processors, retailers/wholesalers, traders, distributors, and restaurateurs). In total, 465 responses were received, indicating a 22% ±1% response rate.[1] Out of the 465 respondents, there are 110 aquaculturists and 2 processors, representing 24% of the total sample. The responses of these 112 aquaculturists/processors, called 'aquaculturists' in the following, are the sample used in this paper. Further explanation and analysis of the survey are presented in Chu (2009, Appendix A).

MODEL SPECIFICATION

The goal of this study is to estimate the relationship between aquaculturists' intended actions of operation expansion and their market expectations, perceptions of the regulatory climate, as well as characteristics of their firms and demographics.

Dependent Variables: Expansion Abroad

The dependent variable is *EXPAND_ABROAD*, representing the intended actions of aquaculturists regarding operation expansion abroad over the next three years. *EXPAND_ ABROAD* takes values of 0, 1, and 2, representing intended action 'no,' 'yes,' and 'uncertain,' respectively. The majority of aquaculturists choose not to expand abroad (56%). About one-quarter of aquaculturists (24%) are planning to expand operations abroad. However, they are generally large firms, representing about 80% of employment in the sample. Nearly 20 aquaculturists (18%) select 'Uncertain/Don't know.'

Independent Variables

Assuming no institutional or regulatory constraints, on-site expansion is generally the most practical and cheapest way to increase production capacity (Schmenner 1980). Expansion abroad is more akin to a relocation problem. The main forces driving relocation decisions usually include seeking more suitable premises, cost savings, easier access to raw materials, lower tax rate, less strict regulations, and market-oriented strategies (Brouwer, Mariotti, and Ommeren, 2004). There are two types of independent

[1] There is an unavoidable double counting problem due to repeated contact information.

variables. The first group is related to perceptions of aquaculturists. Perceptions and expectations are integral factors which affect decision making (Levitt and Dubner, 2005; Evan and Garling, 1991), but few studies have explored the perception-intended action relationship in the aquaculture field (Robertson, Carlsen, and Bright, 2002; Tango-Lowy and Robertson, 2002; Budis, Doto and Moonan, 2003; Mazur and Curtis, 2008). Some key perceptions of aquaculturists will be used as explanatory variables. These aspects include: (a) market expectations, (b) regulatory climate, (c) property rights, (d) government leadership, and (e) comparative advantages of U.S. aquaculture. The second group is associated with demographic characteristics of aquaculturists and their farms, including farm size, farmed species and environment, and education level of aquaculturists. Table 1 summarizes the definition of the explanatory variables and the statistical results.

Explanatory Variable Group 1: Aquaculturists' perceptions

Market Expectations

Market factors are expected to have a strong impact on an aquaculture firm's expansion decision. Whether to expand aquaculture operations is partly determined by the aquaculturists' expectations of seafood demand. International trade makes the market potential in one country available globally. Aquaculturists were asked if they expect seafood demand in their major markets to increase over the next three years (*DEMAND*). A five-point scale is used to represent answers ranging from 'rapid decrease' (-2) to 'rapid increase' (+2). Aquaculturists who are considering expanding production capacity abroad have significantly higher expectations of seafood demand than those who choose 'no' or 'uncertain' at the 1% significance level.

Regulatory Climate

Lockwood (2001b) describes how multitude permitting and regulatory agencies can 'kill' the aquaculture industry. To measure aquaculturists' perceptions regarding the stringency of permit regulations, the explanatory variable, *PERMIT*, is used. It is hypothesized that when aquaculturists think the U.S. permit regulations are too strict, the more likely they will be to expand their production capacity abroad. A five-point scale is used to represent answers from 'very lenient' (-2) to 'very strict' (+2). The mean value for aquaculturists who intend to expand their operations abroad is 1.41, significantly higher than those who choose 'no' (0.81) and those who choose 'uncertain' (0.95) at the 5% and 10% significance levels, respectively. This suggests that perceptions regarding strictness of permit regulations are potentially one of the factors explaining the reasons why to expand operations abroad.

A common argument about environmental regulations is that businesses will move to areas where environmental regulations are relatively weak or under less control (Bartik 1988). Wirth and Luzar (2001) observed that the stringency of environmental regulations can significantly influence the location, growth, and expansion decisions of aquaculture operations. Complying with environmental regulations costs time and money, and often involves risks and uncertainties. Therefore, it can represent a substantial barrier to expansion of the aquaculture industry (Jin, Kite-Powell, and Hoagland, 2005; Diagne, Keithly, and Kazmierczak, 2004). The explanatory variable, *US_ENVREG*, is employed to represent responses of aquaculturists to the question regarding if environmental regulations are strictly enforced in the U.S.A. A five-point scale represents answers from 'strongly disagree' (-2) to 'strongly agree' (+2). It is hypothesized that the strictness of environmental regulations related to aquaculture will have a positive effect on expansion abroad. Mean values around 1.5 for each intended action indicate the average attitude of aquaculturists concerning the enforcement of environmental regulations in the U.S.A. is 'strict' no matter which action they will take (Table 1).

Property Rights

Strong property rights are necessary for intensive aquaculture production since they will provide lease holders incentives to conduct long-term planning such as: adopting new technology, expansion, investment in equipment, conducting research, marketing, and integration (Anderson 2002). Property rights also provide a measure of the regulatory climate, which has an impact on aquaculturists' intended

actions regarding where to establish their farms (Wirth and Luzar, 2001). Transferability is one of the key characteristics of strong property rights. Respondents were asked if aquaculture leases should be transferable (*TRANSFERABLE*). It is hypothesized that aquaculturists' perceptions regarding the transferability will have a positive effect on their decision to expand abroad. Table 1 illustrates all mean values of *TRANSFERABLE* are above 1, suggesting that aquaculturists think aquaculture leases should be transferable.

Table 1 Mean Comparison between Aquaculturists

Variable	Description	Answer Code	Expand Abroad? Yes	No	Not Sure
		Perceptions			
DEMAND	Seafood demand in major market	-2:Rapid Decrease -1: Decrease 0: Stable 1: Increase 2: Rapid Increase	0.92 (0.11)	0.33*** (0.10)	0.22*** (0.17)
PERMIT	Perception regarding the strictness of permit/license process regulations	-2:Very Lenient -1: Lenient /Balanced 0: Uncertain 1: Strict 2: Very Strict	1.41 (0.13)	0.81** (0.15)	0. 89 (0.24)
US_ENVREG	Environmental regulations are generally strictly enforced in the U.S.A.		1.48 (0.12)	1.30 (0.12)	1.58 (0.14)
TRANSFERABLE	Aquaculture lease should be transferable		1.52 (0.14)	1.33 (0.13)	1.61 (0.23)
LACK_LEAD	Lack of clear government leadership has limited aquaculture development	-2:Strongly Disagree -1: Disagree 0: Neutral 1: Agree 2: Strongly Agree	1.59 (0.16)	1.21* (0.13)	1.39 (0.30)
US_DMS_MKT	The U.S.A. has a comparative advantage in terms of access to the domestic markets		1.50 (0.15)	1.04** (0.13)	1.32 (0.19)
US_SKILL_LBR	The U.S.A. has a comparative advantage in terms of skilled labor availability		0.52 (0.25)	0.32 (0.15)	0.11 (0.27)
		Demographic Characteristics			
EMPLOYEE	No. of permanent full time equivalent employees in 2007	Open question	84 (31)	7*** (2)	68 (46)
ENVIRONMENT	Operation environment	0: Freshwater 1: Marine	0.85	0.55***	0.79
SHELLFISH	Most familiar with shellfish	0: No 1: Yes	0.41	0.42	0.21*
EDUCATION	Highest education level	1: High school 2: Bachelor 3: Graduate 4: Other	2.67 (0.13)	2.48 (0.10)	2.53 (0.12)

* Significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.
Standard errors are in parentheses. ANOVA and ANOVACONTRAST are used to compare mean differences (StataCorp 2005).

Government Leadership

Government leadership is potentially another important aspect that might affect aquaculturists' intended actions regarding aquaculture expansion. Lockwood (2001a) compared French oyster farms versus

English, Canadian salmon farms versus American, and California abalone farms versus Mississippi catfish farms, and concluded that "the common denominator for states with robust aquaculture production is strong central advocacy within government. The common denominators for those losing at the aquaculture game are entrepreneurs attempting to emerge in an environment with Neild's incoherent framework of higgledy-piggledy institutions" (p. 38).

Currently, at the federal level, the Food and Drug Administration (FDA) of the Department of Health and Human Service (DHHS), the Department of Agriculture (USDA), and the Environmental Protection Agency, are the leading federal agencies. Additionally, the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce is claiming to have authority to regulate (block permits) aquaculture for federally managed fish species. Other agencies, such as the Joint Subcommittee on Aquaculture, the Center for Veterinary Medicine (FDA), the Animal and Plant Health Inspection Service (USDA), and the U.S. Fish and Wildlife Service (FWS) of the Department of the Interior all have some degree of regulatory authority on different aspects of aquaculture production and marketing (FAO, 2010). At the state level, aquaculture is either under the authority of state departments of agriculture, state departments of game and fish, and/or state departments of environmental management, plus county and/or town level government and/or councils, which will have different effects on regulatory stringency. Moreover, the varying rules and regulations across states, such as the legal size of fish and transportation restrictions, make it difficult for aquaculturists to conduct business across states and thus difficult to integrate resources across states.

All these indicate weak government leadership and uncoordinated policies. It is expected that aquaculturists' perceptions about government leadership will influence their intended actions to expand production capacity. Aquaculturists were asked if they agree that lack of clear government leadership has limited aquaculture development (*LACK_LEAD*). They could choose one of the five answers, from 'strongly disagree' (-2) to 'strongly agree' (+2). Aquaculturists who intend to expand their operations abroad demonstrate a significantly higher mean value (1.59) than those who do not (1.21) at the 10% significance level, but not significantly different from those who are uncertain (1.39).

Comparative Advantages of U.S. Aquaculture

The last perception explanatory variables involve aquaculturists' perceptions regarding the U.S. comparative advantages in aquaculture. In general, it is expected that if aquaculturists perceive that the U.S.A. has strong comparative advantages in aquaculture, they are more likely to expand domestically. Aquaculturists were asked to evaluate 11 aspects of comparative advantages, such as hatchery technology, genetic research, access to the domestic markets, skilled labor availability, disease control, feed production, geographical location, processing, capital availability, offshore aquaculture technology, and management expertise. Based on preliminary analysis, [2] it was found that two of them have significant influence on aquaculturists' intended actions for expansion abroad, including a comparative advantage regarding access to the domestic markets (*US_DMS_MKT*), and skilled labor availability (*US_SKILL_LBR*). Aquaculturists who intend to expand abroad show significantly higher mean on *US_DMS_MKT*, but not on *US_SKILL_LBR* compared to those who choose 'no' or 'uncertain.'

Explanatory Variable Group 2: Aquaculturists' Demographic Characteristics

Four explanatory variables are included in this category. Firm size, coupled with other factors such as age, growth rate, innovation, and market size determines the firm's survival probability (Dunne and Hughes, 1994; Mata and Portugal, 1994). Brouwer *et al.* (2004) showed that larger firms have increased ability to expand abroad. As a proxy for farm size, the number of permanent employees in their operations (*EMPLOYEE*) was asked. They range from family farms to large international companies.

[2] The dependent variables were regressed on these comparative advantages separately. Two aspects, *US_DMS_MKT* and *US_SKILL_LBR* were found to have the most significant influence.

Aquaculturists who intend to expand abroad indicate a significantly larger number of permanent employees (84) than those who choose 'no' (7) at the 1% significance level.

Farming environment is of interest because of the historical production differences between freshwater aquaculture and marine aquaculture; different levels of agency control; and efforts to introduce open-ocean aquaculture in the future. As mentioned above, the regulatory environment is complex. In the past, freshwater aquaculture (especially catfish farming) dominated the U.S. aquaculture sector, nearly double the production of U.S. marine aquaculture in 2007. Even though open-ocean aquaculture is regarded as one of the most likely area for major expansion of U.S. marine aquaculture (U.S. Commission on Ocean Policy, 2004; Marine Aquaculture Task Force, 2007; NOAA, 2008; Jin, Kite-Powell, and Hoagland, 2005), efforts to pass the National Offshore Aquaculture Act have failed twice in the past five years. In addition, freshwater and marine water involve different aquaculture technologies, species, equipment, environment, and systems. Marine aquaculture, conducted in the public domain rather than on private land, usually encounters more difficulties than freshwater aquaculture due to water use conflicts, opposition from coastal land owners, concerns about potential pollution, disease outbreaks, and interbreeding. Therefore, a dummy variable, *ENVIRONMENT*, is created; '1' represents marine aquaculture and '0' otherwise. It is hypothesized that aquaculturists who are considering expansion abroad are more likely to be marine aquaculturists than those who are not.

The species groups include 'Finfish,' 'Shellfish'(molluscan), 'Salmon,' and 'Shrimp' and are respondents' answers regarding their most familiar species, with particular attention to two controversial species groups, 'Salmon' and 'Shrimp.' Molluscan shellfish aquaculture is perceived by many to have less environmental impact compared to finfish farming. Thus, molluscan shellfish aquaculture may have a good potential for future expansion in the U.S.A. It is expected that non-molluscan farmers are more likely to expand abroad. A dummy variable, *SHELLFISH*, is created. '1' represents answer "yes", meaning aquaculturists choose shellfish as their most familiar species and '0' otherwise. No significant differences between action groups are found.

Education level (*EDUCATION*) is the last independent demographic variable evaluated in the model. It is hypothesized that the more education aquaculturists have, the more ability they have to expand production capacity abroad. The mean values do not show any significant differences between each action group. It should be noted that most aquaculturists have at least a bachelor's degree and many have completed graduate study.

EMPIRICAL RESULTS OF THE INTENDED ACTIONS TO EXPAND OPERATION ABROAD

Models 1-4 estimate the relationship between aquaculturists' intended action to expand production capacity abroad during the next three years and the explanatory variables mentioned.

Model 1: Multinomial Probit Model

Model 1 is a multinomial probit model (see columns 2 & 3 in Table 2). The explanatory variables, which have the most significant impacts on aquaculturists' intended actions to expand production capacity abroad, are expectations regarding seafood demand (*DEMAND*), number of permanent employees (*EMPLOYEE*), aquaculture environment (*ENVIRONMENT*), and farmed species (*SHELLFISH*). The higher demand aquaculturists expect in their major market over the next three years, and the more employees they have, the more likely they will expand abroad. Marine aquaculturists are significantly more likely to expand abroad compared to freshwater aquaculturists. The coefficient on *SHELLFISH* is -2.41, indicating molluscan shellfish aquaculturists are significantly less likely to expand abroad. A potential reason might be that the molluscan shellfish producers may have had a tough time getting access to markets abroad or they may not have the capital or energy to seek other sites abroad. The explanatory variable, *TRANSFERABLE*, has a positive impact on aquaculturists' intended actions to expand abroad at the 10% significance level. This indicates that the more aquaculturists agree aquaculture leases should be

transferable, the more likely they are to intend to expand their operations abroad. These are all consistent with the hypotheses.

Some aquaculturists are uncertain if they will expand their production abroad in the next three years. This is understandable. Investment in aquaculture is characterized as relatively irreversible since the equipment is industry-specific and difficult to transfer to other purposes (Jin, Kite-Powell, and Hoagland, 2005). The difficulty of retrofitting aquaculture equipment for other purposes, along with regulation and business uncertainty determine some of the aquaculturists' hesitation to take actions regarding expanding their operations abroad. Furthermore, assessing and locating sites are not easily undertaken. Compared to the results of 'yes' versus 'no,' more explanatory variables become significant in affecting aquaculturists' intended actions to choose 'uncertain.' All of the explanatory variables, except *PERMIT*, have the same estimated signs as those who select 'yes.' This indicates aquaculturists who are not sure if they are going to expand abroad are thinking similarly to those who are planning to expand abroad. Aquaculturists who choose 'uncertain' are those who think that: aquaculture leases should be transferable, lack of clear government leadership has limited aquaculture development), the U.S.A. does not have comparative advantages in skilled labor availability, and the U.S.A. has comparative advantages regarding access to domestic markets. They also tend to be large companies, and non-molluscan farmers. Additionally, marine aquaculturists are more likely to choose 'uncertain' than 'no' at the 10% significance level. These are all consistent with the hypotheses.

Model 2: Multinomial Probit Model with Limited Explanatory Variables

In Model 2, insignificant variables in Model 1 for alternative action 'yes' are dropped (see columns 4 & 5 in Table 2), including the regulatory climate variables (*PERMIT* and *US_ENVREG*), government leadership variable (*LACK_LEAD*), U.S. comparative advantage variables (*US_SKILL_LBR* and *US_DMS_MKT*), and education level variable (*EDUCATION*). Compared to Model 1, Model 2 obtained more observations, becomes significant at the 1% significance level and also fits better based on AIC and BIC values. However, *TRANSFERABLE* turns to be insignificant. All of the significant variables have the same estimated signs as Model 1.

Model 3: Probit Model

In order to more clearly identify the factors influencing aquaculturists' intended actions to expand production capacity abroad, a probit model is used to compare intended actions 'yes' versus 'no'. Model 3 uses the same explanatory variables as Model 1 (see columns 6 & 7 in Table 2). All of the explanatory variables are significant except *LACK_LEAD*. Compared to Model 1, both the regulatory climate variables (*PERMIT* and *US_ENVREG*) and U.S. comparative advantage variables (*US_SKILL_LBR* and *US_DMS_MKT*) become significant in influencing aquaculturists' intended actions to expand abroad in Model 3 at the 10% significance level. The stricter they perceive permit regulations and environmental regulations to be, the more likely they will be to expand abroad. This is consistent with the hypothesis. Regarding the perceptions of U.S. comparative advantages in skilled labor availability and access to the domestic markets, the positive signs of the coefficients are somewhat inconsistent with expectations. Market advantages might be easy to transfer in international seafood trade, but skilled labor is not. A possible explanation for the positive sign of *US_SKILL_LBR* is those farms looking to expand production abroad may be primarily interested in employing unskilled farm labor abroad. *EDUCATION* becomes significant. The higher the level of education those aquaculturists have, the less likely they will be to expand abroad. This is somewhat inconsistent with the hypothesis. This might be because aquaculturists with higher education have more confidence in conducting aquaculture in the U.S.A. The variable *SHELLFISH* becomes less significant. As in Model 1, *DEMAND*, *EMPLOYEE*, and *ENVIRONMENT* are significant at the 5% significance level, and *TRANSFERABLE* is significant at the 10% significance level.

Table 2 Estimated Coefficients for the Decision to Expand Production Abroad

Explanatory Variables	Dependent Variable: EXPANDOUT							
	Multinomial Probit				Probit			
	Model 1		Model 2		Model 3		Model 4	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
	'yes' vs. 'no'				**'yes' vs. 'no'**			
DEMAND	1.33**	0.53	1.02**	0.41	7.30**	3.45	0.88**	0.34
PERMIT	0.65	0.44			4.96*	2.52		
US_ENVREG	0.20	0.59			2.23*	1.13		
TRANSFERABLE	1.00*	0.51	0.52	0.33	7.46*	3.79	0.57*	0.29
LACK_LEAD	0.48	0.42			-0.37	0.55		
US_SKILL_LBR	-0.21	0.33			2.07*	1.04		
US_DMS_MKT	0.89	0.55			3.00*	1.55		
EMPLOYEE	0.06**	0.02	0.03**	0.01	0.18**	0.08	0.03**	0.01
ENVIRONMENT	2.28**	1.04	1.77**	0.73	15.38**	7.51	1.64**	0.63
SHELLFISH	-2.41**	1.06	-1.58**	0.67	-17.39*	8.81	-1.64**	0.59
EDUCATION	-0.56	0.57			-2.93*	1.54		
Constant	-5.16**	2.26	-3.08***	0.82	-28.14**	13.19	-2.78**	0.75
	'uncertain' vs. 'no'							
DEMAND	0.19	0.52	-0.47	0.36				
PERMIT	-0.77	0.48						
US_ENVREG	0.16	0.73						
TRANSFERABLE	2.41**	0.94	1.13*	0.56				
LACK_LEAD	3.12**	1.37						
US_SKILL_LBR	-1.12**	0.42						
US_DMS_MKT	1.60**	0.62						
EMPLOYEE	0.07**	0.03	0.03**	0.01				
ENVIRONMENT	2.93*	1.59	1.80**	0.78				
SHELLFISH	-3.63**	1.41	-1.78**	0.70				
EDUCATION	-0.60	0.74						
Constant	-11.80**	4.62	-3.65**	1.07				
Statistics								
No. of Obs.		75		82	No. of Obs.	62		68
Wald chi2		24.95		29.07	LR chi2 (11)	66.19		43.79
Prob > chi2		0.30		0.00	Prob > chi2	0.00		0.00
					Pseudo R2	0.82		0.50
Log likelihood		-34.08		-54.18	Log likelihood	-7.23		-21.61
BIC		171.77		161.27		63.98		68.56
AIC		116.15		132.39		38.46		55.24

Base level is decision 'no' for multinomial probit models.
* Significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

Model 4: Probit Model with Limited Explanatory Variables

Model 4 uses the same limited explanatory variables as in Model 2 (see columns 8 & 9 in Table 2). Compared to Model 3, Model 4 obtains more observation. All its explanatory variables have the same effects on the dependent variables as in Model 3, but Model 4 does not fit better than Model 3 based on BIC and AIC.

Summary

Overall, Model 3 fits the best if the focus is solely on the intended expansion abroad and factors affecting the aquaculturists' intended actions to choose 'yes' over 'no.' The results of Model 3 indicate large non-

molluscan (i.e. finfish, salmon, or shrimp) less-educated marine aquaculturists with high expectations on seafood demand over the next three years, who think U.S. permit and environmental regulations are strict, aquaculture leases should be transferable, and the U.S.A. has comparative advantages in skilled labor availability plus access to the domestic markets are more likely to expand their operations abroad.

Based on Model 3, the marginal effects are analyzed (Table 3). For the continuous explanatory variable, *EMPLOYEE*, the probability that an aquaculturist decides to expand operations abroad will increase by about 0.003 for an additional permanent employee. For the dummy variables, *ENVIRONMENT* and *SHELLFISH*, the probability change is close to 1 when the farm environment changes to marine and species change to shellfish. Therefore, unless there are offsetting factors, it seems marine, non-molluscan (finfish, salmon, and shrimp) aquaculturists tend to expand abroad while holding other variables at their means.

Table 3 Marginal Effects for the Decision to Expand Production Abroad Based on Model 3

Expand Abroad	Marginal Effect	Standard Error	Mean
DEMAND	0.121**	0.399	0.452
PERMIT	0.081**	0.270	1.016
US_ENVREG	0.037**	0.128	1.435
TRANSFERABLE	0.124**	0.410	1.258
LACK_LEAD	-0.006	0.018	1.403
US_SKILL_LBR	0.034**	0.114	0.339
US_DMS_MKT	0.050*	0.169	1.177
EMPLOYEE	0.003**	0.010	31.274
ENVIRONMENT	1.000**	0.002	0.613
SHELLFISH	-1.000**	0.000	0.371
EDUCATION	-0.049*	0.164	2.548

* Significant at the 10% level; ** significant at the 5% level.

Additionally, the predicted probability of aquaculturists' intended actions to expand abroad can be calculated by using the coefficients of Model 3. Figure 1 demonstrates one example of this analysis. It indicates that larger companies are more likely to expand operations abroad when holding all the other parameters constant (at their means). It suggests that the US acts as an 'incubator': small firms with highly educated managers start here, and if they are successful and want to grow, they plan to leave the country and expand abroad. Chu (2009) shows more detailed results for other variables.

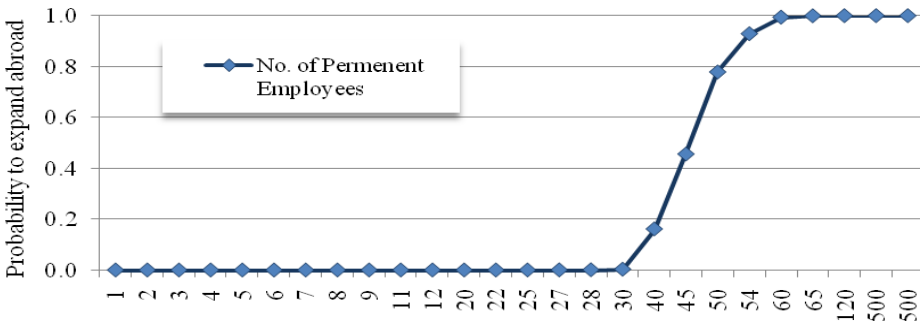

Figure 1 Effects of No. of Permanent Employees on the Probability of Aquaculturists' Decision to Expand Production Capacity Abroad

DISCUSSION AND CONCLUSION

This paper attempts to answer the question why some aquaculturists intend to expand/invest production capacity abroad. It analyzes the primary online data collected from 112 aquaculturists. The results of

multinomial probit and probit models indicate that large-scale, non-molluscan (e.g., finfish, salmon, or shrimp), less-educated, marine aquaculturists with high expectations about seafood demand during the next three years; who think U.S. permit and environmental regulations are strict; that aquaculture leases should be transferable; and that the U.S.A. has comparative advantages in skilled labor availability and access to the domestic markets, are more likely to expand their operations abroad.

These findings partially explain why marine aquaculture has not fully developed in the U.S.A. and provide guidance for U.S. policy makers to help retain aquaculture entrepreneurs and investors domestically. If the U.S.A. wants to further develop aquaculture, retain entrepreneurs, or benefit from the economic returns, then the government needs to improve the regulatory environment so that aquaculturists will have confidence to expand their operations domestically. It will be helpful to streamline the permit application or renewing process, and ensure the transferability of aquaculture leases. Establishing legislation for offshore aquaculture will provide regulatory certainty and large farming potential for U.S. marine aquaculture.

The net seafood demand determines the future and size of aquaculture industry (Jin, Kite-Powell, and Hoagland, 2007). Whether it will be in the U.S.A. or other countries depends on the production costs and productivity comparison. Without the leadership of government and coherent policies, it is difficult to envision aquaculture developing as fast in the U.S.A. as other aquaculture producing countries, such as China and Norway. The fact that about one-quarter of aquaculturist firms represented in the survey (approximately 80 percent of employment) are planning expansion of their production abroad should get policy makers' attention regarding how to realize institutional innovations to encourage investments in the U.S.A.

Whether the U.S.A. supports aquaculture or not, the trend of more farmed products on the restaurant menu or household table will not change. The reality is that U.S. seafood consumption will continue to rely more heavily on imports in the near future. Offshore aquaculture has begun to develop in countries such as Norway, Korea, Mexico, and China. If the U.S.A. does not take advantage of the technology and its broad coastal areas with the enabling institutions, more opportunities, not only in aquaculture, but also in aquaculture-related industries such as processing, manufacture of equipment, and feed production will move abroad.

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