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Lobster farming in Vietnam: the relationship between being cost efficient and environmentally efficient

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Abstract:

Marine cage lobster in Vietnam has been known as a high return industry. But in recent years, it has also been facing with negative feedback on productivity due to overuse of nutrient content inputs. Local lobster farmers seemed to internalize this negative feedback by paying more efforts on cleaning cage and more cost on antibiotics and chemical without knowing if it is a positive or negative economic-environmental trade-off. In order to identify the relationship between the cost and environmental efficiency, this paper used Data Envelopment Analysis and Material Balance Principle with a dataset of 353 marine cage lobster farms in Vietnam. The findings show that improvements in efficiency of current input used would result in both lower production costs and better environmental performance. There is a positive trade-off in most lobster farms for being environmentally efficient and cost efficient from the current production. If lobster farms used appropriate input mix given input price information to be more cost efficient, it would benefit to environment. Moreover, producing friendlier with the marine environment also reduce production cost. However, there is a negative trade-off for the movement from being cost efficient to environmentally efficient position for all three groups.

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Abstract

Marine cage lobster in Vietnam has been known as a high return industry. But in recent years, it has also been facing with negative feedback on productivity due to overuse of nutrient content inputs. Local lobster farmers seemed to internalize this negative feedback by paying more efforts on cleaning cage and more cost on antibiotics and chemical without knowing if it is a positive or negative economic-environmental trade-off. In order to identify the relationship between the cost and environmental efficiency, this paper used Data Envelopment Analysis and Material Balance Principle with a dataset of 353 marine cage lobster farms in Vietnam. The findings show that improvements in efficiency of current input used would result in both lower production costs and better environmental performance. There is a positive trade-off in most lobster farms for being environmentally efficient and cost efficient from the current production. If lobster farms used appropriate input mix given input price information to be more cost efficient, it would benefit to environment. Moreover, producing friendlier with the marine environment also reduce production cost. However, there is a negative trade-off for the movement from being cost efficient to environmentally efficient position for all three groups.

Introduction

Marine cage lobster farming has been known as not only being an important aquaculture activity, but also having a significant positive impact on livelihoods in impoverished coastal communities in Vietnam (FAO, 2011; Minh et al., 2015; Petersen & Phuong, 2010). However, disease and disease outbreak are major constraints that most of Vietnamese lobster farms has already experienced in recent years (FAO, 2011; Minh et al., 2015). This issue is supposed to relate to the overuse of trash fish lead to large inputs of organic matter and consequential pollution (FAO, 2011; D. H. Hoang, Sang, Kien, & Bich, 2009). Estimation of the nitrogen loading released into the marine environment to produce one tone of lobster were 204 kilograms in the study of Chien (2005), 389 kilograms in the study of Ly (2009) and 257.5 kilograms in study of An and Tuan (2012). As a result the sector has been facing with a number of environmental problems in the form of nutrients surpluses (Hung, Khuong, Phuoc, & Thao, 2010; Lee, Hartstein, & Jeffs, 2015a, 2015b; Wu, 1995). Lowering the resistance to diseases and thereby having negative feedback effects on lobster productivity (Asche & Tveteras, 2005; Minh et al., 2015) is one of the visible consequences (FAO, 2011; Hung & Tuan, 2009; Tuan, 2011). The local lobster farms seemed to internalize these effects by paying more efforts on cleaning lobster cage frequently to reduce pollution and by paying more cost on antibiotics and chemicals in treatment of disease rather than by using less nutrient content inputs. This implies a perception of decreasing pollution is costly and lead to less economic efficiency or a negative economic-environmental trade off (Meensel, Lauwers, Huylenbroeck, & Passel, 2010) in lobster farming in Vietnam. However, reducing environmental pressure does not always associate with threat to economic outcome. Some studies showed that both economic and environmental objectives can be achieved simultaneously by using inputs more efficiently (Meensel, Lauwers, &

Huylenbroeck, 2010; Meensel, Lauwers, Huylenbroeck, et al., 2010) or that can be called as a positive economic-environmental trade off (Meensel, Lauwers, Huylenbroeck, et al., 2010).

In order to provide farms a better guidance for reducing the pollution and improving economic performance thereby maintaining their competitiveness in harmony with the environment, this paper aims to examine if cost efficiency of lobster farms in Vietnam really deviates from environmental efficiency and if using inputs more environmentally efficient will cost or benefit to the farms. The economic-environmental trade-off of lobster farming in Vietnam from the current and cost efficient operations to environmentally efficient operations, therefore, have to be explored.

Methodology

Materials Balance Principle (MBP)

Up to now, there has been many studies introduced environmental effect as either a bad output or an environmentally detrimental input into production function in measuring environmental efficiency (Färe, R., Grosskopf, S., Tyteca, 1996; Fare, Grosskopf, Knox Lovell, & Pasurka, 1989; Pittman, 1983; Reinhard, Knox Lovell, & Thijssen, 2000; Tyteca, 1997). This might be inconsistent with the rule of materials balance principle (Coelli, Lawers, & Huylenbroeck, 2007; V. N. Hoang & Coelli, 2011). Coelli et al. (2007) firstly proposed to base on this materials balance principle to measure environmental efficiency of Belgian pig-finishing farms. It does not introduce any extra variable into production model as in previous studies. This approach, then, has been applied in many other studies in agriculture production (V. N. Hoang & Alauddin, 2012; V. N. Hoang & Coelli, 2011; V. N. Hoang & Nguyen, 2013; Thanh Nguyen, Hoang, & Seo, 2012)

The MBP is the rule of “what go in must go out” of mass conservation. It regulates the transformation of materials in such closed systems of agricultural production. The MBP implies that the balance of nutrient equals the nutrient in inputs minus the nutrient in output. And this balance of nutrients is considered as polluting emissions in this study.

Consider the case of n farms or decision making units (DMUs). Each farm uses K inputs (x) to produce M conventional outputs (y). This production also produces an emission of polluting substance (z). The amount of emission is defined by the balance of nutrients based on Materials balance principle (MBP):

$$Z = a'x - b'y$$

Where a and b are nutrient content in inputs and outputs. It is possible that some inputs could almost have zero amounts of nutrients. And the vectors a of those inputs may include zero values.

Data envelopment analysis (DEA) for cost and environmental efficiency

The nutrient from producing lobster release to marine environment from above formulation was considered as potential damage or pollution in this study. This pollution will be least with the minimum nutrient balances. When the output y is constant, the nutrient balances will be minimized if the nutrient content in input x is minimized. The pollution minimization is defined in the same manner as cost minimization using input-oriented DEA model, where nutrient content is treated as input price. The DEA models for defining the cost and nutrient minimization are:

Cost minimization

$$Min_{\lambda, x_i^{CE}} w_i^{'} x_i^{CE}$$

Subject to

$$-y_i + Y\lambda \geq 0,$$
$$x_i^{CE} - X\lambda \geq 0,$$
$$\sum_{i=1}^{N} \lambda_i = 1$$
$$\lambda \geq 0$$

Nutrient minimization

$$Min_{\lambda, x_i^{EE}} a_i^{'} x_i^{EE}$$

Subject to

$$-y_i + Y\lambda \geq 0,$$
$$x_i^{EE} - X\lambda \geq 0,$$
$$\sum_{i=1}^{N} \lambda_i = 1$$
$$\lambda \geq 0$$

Where w_i is a vector of input prices for i-th farm, x_i^{CE} and x_i^{EE} are the cost minimizing vector and nutrient minimizing vector of input quantities for i-th farm, λ is vector of constants, and all other notation is as previously defined.

The cost and environmental efficiencies are defined as the ratios of minimum cost (minimum nutrient content) over observed cost (observed nutrient content):

Cost efficiency (CE):

$$CE = w_i' x_i^{CE} / w_i' x_i$$

Environmental efficiency (EE):

$$EE = a_i' x_i^{EE} / a_i' x_i$$

With x_i^{TE} is the input vector at which the farm is technical efficient, technical efficiency (TE) is defined as:

$$TE = \frac{x_i^{TE}}{x_i} = \frac{w_i' x_i^{TE}}{w_i' x_i} = \frac{a_i' x_i^{TE}}{a_i' x_i}$$

The input orientated cost and environmental efficiency can be decomposed into technical efficiency and cost (environmentally) allocative efficiency as follow:

$$CE = \frac{w_i' x_i^{CE}}{w_i' x_i} = \frac{w_i' x_i^{CE}}{w_i' x_i^{TE}} \times \frac{w_i' x_i^{TE}}{w_i' x_i} = CAE \times TE \qquad EE = \frac{a_i' x_i^{EE}}{a_i' x_i} = \frac{a_i' x_i^{EE}}{a_i' x_i^{TE}} \times \frac{a_i' x_i^{TE}}{a_i' x_i} = EAE \times TE$$

Where cost allocative (CAE) and environmentally allocative efficiency (EAE) are derived as:

$$CAE = \frac{w_i' x_i^{CE}}{w_i' x_i^{TE}} \qquad EAE = \frac{a_i' x_i^{EE}}{a_i' x_i^{TE}}$$

Decomposition of and trade-off between cost and environmental efficiency

A graphical representation of the measurement of technical efficiency, cost and environmental allocative efficiency, and cost and environmental efficiency using input orientated DEA shows the intuitive interpretation of above decomposition and the trade-off between cost and environmental efficiency with the nutrient-containing input of x_1 and no nutrient content input of x_2 (Figure 1).

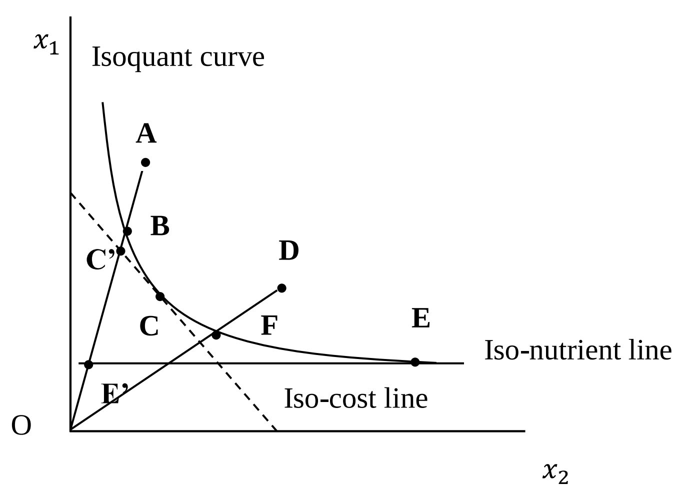

Figure 1: The trade-off between cost and environmental efficiency

From this figure, the technically efficient farms are those that lay on the isoquant curve. Hence, B, C, E and F are technically efficient farms. Meanwhile, A and D are technically inefficient farms. The technical efficiency (TE) of farm A is most commonly measured by the ratio:

$$TE = OB/OA$$

The cost efficiency (CE) of farm A is defined by the ratio:

$$CE = OC'/OA$$

Because the nutrient content in x_2 is zero, to minimize total amount of nutrient release to environment, farms will use x_1 as much as possible. The iso-nutrient, therefore, will be parallel with the horizontal axis. Any farms on this iso-nutrient line release the same amount of nutrient to environment. Hence, E and E' are environmentally allocative efficient points. However, the output at E' point production is lower than at E, which is the intersection between iso-nutrient and iso-quant. E is said to be technical efficient as well as environmentally allocative efficient. And the environmental efficiency (EE) of farm A can be estimated by the ratio:

$$EE = OE'/OA$$

The cost allocative (CAE) and environmentally allocative efficiencies (EAE) of farm A can be calculated by using those above ratios:

$$CAE = \frac{CE}{TE} = \frac{OC'/OA}{OB/OA} = \frac{OC'}{OB} \qquad EAE = \frac{EE}{TE} = \frac{OE'/OA}{OB/OA} = \frac{OE'}{OB}$$

Above decomposition implies that an increase in technical efficiency from A to B (or D to F) will result in an improvement in both cost and environmental efficiencies. The impact of cost allocative or environmentally allocative efficiency on environmental and cost efficiencies, however, depend on where the farms are on the graph. For farm A, a movement from B to C to be cost efficient represents an increase in CAE. It also implies an improvement in environmental efficiency because this movement is on the way to reach E to be environmental efficient. This means that an increase in CAE will result a rise in EE for farm A. On the contrary, an increase in CAE will lead to a fall in EE for farm D because a movement from F to C to be cost efficient of this farm shows a larger distance from environmental efficient point (E). Based on this trade-off, policy intervention can be applied to improve environmental or economic performance by introducing taxes or removing subsidize on nutrient-containing inputs.

Data and variables

Data was collected from marine cage lobster farms in Phu Yen and Khanh Hoa provinces from August to November 2016. Those two provinces were selected as primary sampling units because they account for more than 94% of the total lobster cages in Vietnam (Minh et al., 2015; Petersen & Phuong, 2010). In total 361 farmers were interviewed using a structured questionnaire, which was designed based on the result of expert interviews in July 2016. This covers about 4% of the estimated marine cage lobster farms in the study area. 8 farms were found to be outliers and removed to avoid sensitivity of the DEA approach. The final sample of 353 farms was used in this study. Based on the type of lobster cultivated, the samples were found to be grouped into 150 spiny lobster farms, 166 green lobster farms and 37 mixed cultivation farms. Mixed cultivation means that both types of lobster (spiny and green lobster) are cultivated in the farm, but in different cages. The information of nutrient content in the inputs was based on the study of Chien (2005).

TABLE 1: Description of variables in DEA model

Variables	Description	Unit
Outputs	Total quantity of spiny (green) lobster produced	Kilogram
Inputs for cost efficiency model		
Fingerling cost	Cost of spiny (green) fingerling cultivated per production cycle	VND
Feed cost	Trash fish cost for feed per production cycle	VND
Labor cost	Cost of total working hours used per production cycle	VND
Inputs for environmental efficiency model		
Feed nutrient	Total quantity of nitrogen content in trash fish for feed	Kilogram

Results and discussion

The cost and environmental efficiency scores of lobster farms are summarized in Table 2. The average cost efficiency scores for spiny lobster, green lobster and mixed cultivation were estimated to be 0.641, 0.679 and 0.859. And the mean environmental efficiency scores were only 0.447, 0.510, and 0.693 respectively. This implies that these farms were producing not only cost inefficiently but also substantially environmentally inefficient. Compared to the best practice, on average, spiny lobster, green lobster, and mixed cultivation farms should be able to produce their current output with an input bundle that contains 55.3%, 49%, and 30.7% less nutrient respectively. This reduction would mean that less pollution is released or less potential damage is caused to the marine environment.

Frequency distributions of the estimated efficiency scores are depicted in Figure 2. The majority of spiny lobster and green lobster farms have cost efficiency index within the range of 0.6-0.8. The range of environmental efficiency index was within only 0.2-0.4 for the former but 0.4-0.6 for the later. Most of mixed cultivation farms have cost efficiency range from 0.8 to 1 and environmental efficiency range from 0.6 to 0.8. This Figure and the results in Table 5 also indicate that for spiny lobster group, only 2% (3 out of 150 farms) was cost efficient and 3.3% (5 out of 150 farms) was environmentally efficient. For green lobster group, there were 5.4% (9 out of 166 farms) cost efficient farms and 3.6% (6 out of 166 farms) environmentally efficient farms. This number was much higher for mixed cultivation group with 24.3% (9 out of 37) and 18.9% (7 out of 37) respectively. The high result for mixed cultivation group might be due to its smaller sample size. These show great potential to improve both economic and environmental performance of lobster farms in Vietnam.

Table 2: Cost and environmental efficiency score using standard input-orientated VRS DEA

	Spiny lobster			**Green lobster**			**Mixed cultivation**		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
TE	0.8390	0.4839	1.0000	0.7722	0.2969	1.0000	0.9610	0.6560	1.0000
CAE	0.7642	0.4193	1.0000	0.8831	0.4411	1.0000	0.8902	0.4193	1.0000
CE	0.6408	0.2936	1.0000	0.6792	0.2819	1.0000	0.8590	0.3914	1.0000
EAE	0.5326	0.1506	1.0000	0.6550	0.2679	1.0000	0.7144	0.2845	1.0000
EE	0.4465	0.1044	1.0000	0.5096	0.1058	1.0000	0.6933	0.2204	1.0000

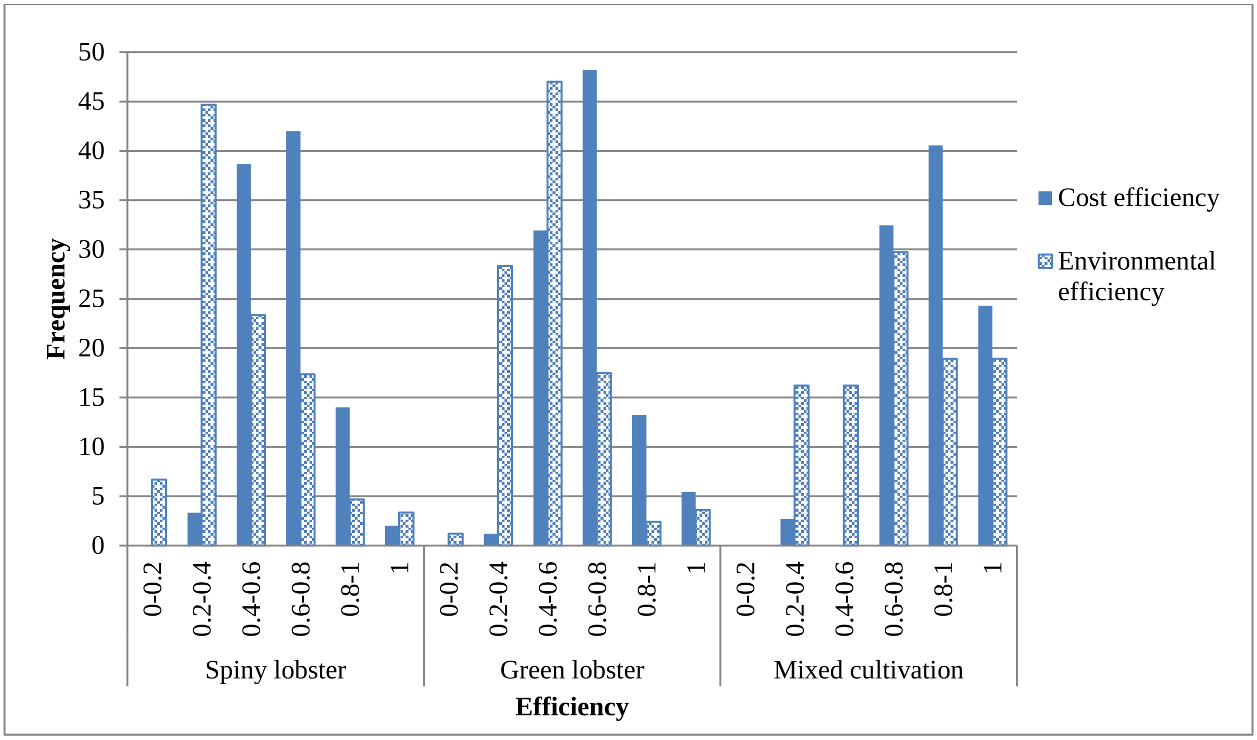

Figure 2: Frequency distribution of cost and environmental efficiency

Figure 3 compares environmental efficiency by subgroups of 10% most cost efficient farms, 10% most cost inefficient farms and 10% farms closest to the average cost efficiency for spiny lobster, green lobster and mixed cultivation groups.

In general, this figure shows the positive relationship between environmental efficiency and cost efficiency score for all three groups. The more cost efficient the more environmentally efficient the farms are although the deviate is not such clear in environmental efficiency score for spiny lobster between 10% most cost efficient group (0.55) and 10% farms closest to the average cost efficiency (0.54). This positive relationship is confirmed by the correlation coefficients and Spearman's rank test for the correlation between efficiency measures in Table 3.

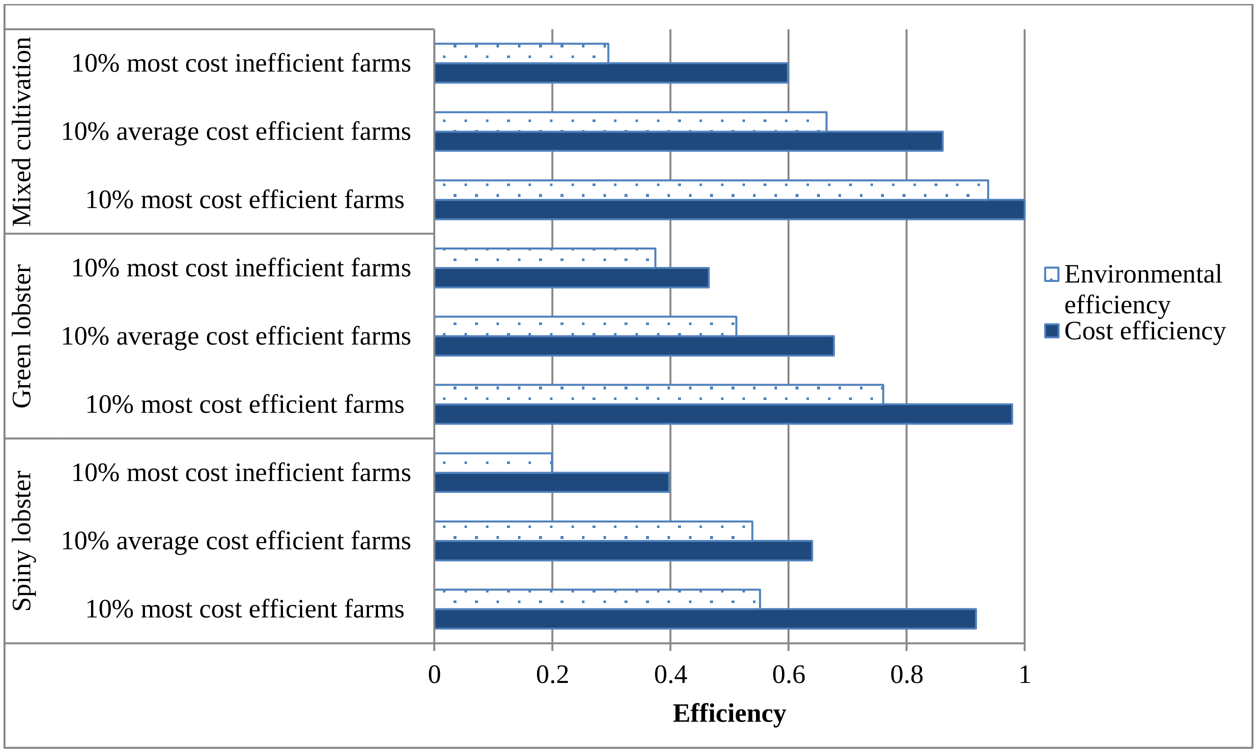

Figure 3: Comparison of environmental efficiency among farms with average cost efficiency, most cost efficiency and most cost inefficiency

Table 3: Spearman correlation between efficiency measures

	EE of spiny lobster	EE of green lobster	EE of mixed cultivation
CE of spiny lobster	0.6511443***		
CE of green lobster		0.6932192***	
CE of mixed cultivation			0.8281178***

The results also show that 88.7% of spiny lobster, 94% of green lobster and 94.6% of mixed cultivation farms have cost efficiency level greater than environmental efficiency level. There were 2 out of 150 spiny lobster farms (accounted for 1.3%), 5 out of 166 green lobster farms (accounted for 3%), and 12 out of 37 mixed cultivation farms (accounted for 32.4%) obtaining both cost and environmental efficiency. This shows that most of lobster production in study area target to cost-minimizing rather than friendlier with environment.

Table 4 and 5 report the relative changes in production cost and nutrient and the number of farms having positive or negative trade-off for four scenarios (1) from the current to cost efficient operation, (2) from the current to environmentally efficient operation, (3) from cost efficient to environmentally efficient position, and (4) from environmentally efficient to cost efficient position.

A positive trade-off implies that economic and environmental performances improve simultaneously, while a negative trade-off implies that economic performances improves, but environmental performance diminishes or vice-versa. Therefore, farms with negative or positive value for both cost and nutrient change have positive cost-environmental trade-off. On the contrary, farms with negative value for cost change and positive value for nutrient change or vice-versa have negative cost-environmental trade-off.

The results in Table 4 and Table 5 show a major trend of positive cost-environmental trade-off in lobster aquaculture in Vietnam. For most farms of all three groups, the movement from the current to both cost efficient position and environmentally efficient position is associated with reductions in both production cost and consumption of nutrient. On average, the movement of spiny lobster, green lobster, and mixed cultivation farms from the current to cost efficient position would not only reduce the production cost by 35.9%, 32.1%, and 14.1% (equivalent to 12,415 USD, 5,729.9 USD, and 4,608 USD respectively) but also reduce 49.6%, 27.3%, and 17.1% of nutrient consumption respectively (equivalent to 77.1 kilogram, 37.7 kilogram, and 42.4 kilogram of nutrient for spiny lobster, green lobster and mixed cultivation farms respectively) without changing in output.

Table 4: The relative change (%) in production cost and nutrient consumption of being cost and environmental efficiency

		Spiny lobster		Green lobster		Mixed cultivation	
		Cost Change	Nutrient change	Cost change	Nutrient change	Cost change	Nutrient change
(1) From the current to CE	Mean	-35.9	-49.6	-32.1	-27.3	-14.1	-17.1
	Min	-70.6	-89.2	-71.8	-80.7	-60.9	-61.5
	Max	0	85.9	0	40.6	0	113.9
(2) From the current to EE	Mean	-19.5	-55.3	-21.8	-49.0	-1.4	-30.7
	Min	-58.5	-89.6	-70.0	-89.4	-53.1	-78.0
	Max	69.9	0	41.7	0	43.2	0
(3) From CE to EE	Mean	26.0	-9.0	16.4	-28.3	16.2	-16.5
	Min	0	-49.7	0	-59.0	0	-53.2
	Max	106.5	0	51.0	0	56.9	0
(4) From EE to CE	Mean	-18.4	12.7	-13.0	46.8	-12.6	24.4
	Min	-51.6	0	-33.8	0	-36.3	0
	Max	0	98.8	0	144.2	0	113.9

If the spiny lobster, green lobster, and mixed cultivation groups were to move to environmentally efficient frontier from the current position, they would not only reduce the nutrient consumption by 55.4%, 49% and 30% (equivalent to 86.2 kilogram, 67.7 kilogram, and 74.4 kilogram of nutrient respectively) but also reduce the production cost about 19.5%, 21.8%, and 1.4% (equivalent to 6,743 USD, 3,891.3 USD, and 457.6 USD respectively).

However, the movement of most lobster farms from cost efficient to environmental efficient position or vice-versa is associated with negative trade-off. If spiny lobster, green lobster and mixed cultivation were moved from cost efficient to environmentally efficient position, the production cost will increase 26%, 16.4%, and 16.2% but the nutrient use will decrease 9%, 28.3%, and 16.5% respectively. And if those lobster farms move from environmentally efficient to cost efficient position, the cost will be reduced by 18.4%, 13%, and 12.6% but the nitrogen used will be increased by 12.7%, 46.8% and 24.4% respectively.

Table 5: Number of farms has positive/negative cost-environmental trade-off

		Spiny lobster		Green lobster		Mixed cultivation	
		Cost Change	Nutrient change	Cost Change	Nutrient change	Cost Change	Nutrient change
(1) From the current to CE	(-)	147	141	157	135	28	24
	(0)	3	3	9	9	9	9
	(+)	0	6	0	22	0	4
(2) From the current to EE	(-)	115	145	150	160	16	30
	(0)	5	5	6	6	7	7

	(+)	30	0	10	0	14	0
(3) From CE to EE	(-)	0	148	0	154	0	32
	(0)	2	2	12	12	5	5
	(+)	148	0	154	0	32	0
(4) From EE to CE	(-)	148	0	154	0	32	0
	(0)	2	2	12	12	5	5
	(+)	0	148	0	154	0	32

Conclusion

The relationship between cost and environmental efficiency of marine cage lobster in Vietnam was explored by using Data Envelopment Analysis and Material Balance Principle with a dataset of 353 farms. The mean relative changes were -35.9%, -32.1%, and -14.1% in production cost and -49.6%, -27.3%, and -17.1% in nutrient consumption for spiny lobster, green lobster and mixed cultivation farms respectively when they move from the current to cost efficient position. They were -55.4%, -49% and -30% in nutrient consumption and -19.5%, -21.8%, and -1.4% in production cost respectively when the farms move from the current to environmentally efficient position. These findings show that improvements in efficiency of current input used would result in both lower production costs and better environmental performance. There is a positive trade-off in most lobster farms for being environmentally efficient and cost efficient from the current production. If lobster farms used appropriate input mix given input price information to be more cost efficient, it would benefit to environment. Moreover, producing friendlier with the marine environment also reduce production cost.

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