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Analysis of supply response of black tiger shrimp production using Nerlove model

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A B S T R A C T

This study aims to analyze the effect of black tiger shrimp price and other factors on the shrimp area in the Mekong Delta using the supply response function based on the Nerlovian partial adjustment model. Using quarterly panel data collected from four provinces (Ca Mau, Bac Lieu, Soc Trang, and Kien Giang) for the period of 2014 to 2017, the estimates in the supply response are obtained from Fixed-Effects (FE) method. Results indicate that the adaptive expectation hypothesis to the simple Cobweb model is likely to best fit the data. The estimates of the supply response model show that information used for expected price formation quickly responded in making a decision of black tiger shrimp production. In both the short run and long run, the expected price has a significant effect in directing black tiger shrimp farmers to formulate the supply response decision. The acreage response elasticity is more elastic.

1. Introduction

The study of supply response and elasticity is an important scientific field that attracts economists and policymakers. It sought to quantify the effects of changes in government programs on prices and trade policies for inputs, outputs, and responses of producers. However, in Vietnam, particularly in Mekong Delta, very few quantitative studies relating to a supply of agricultural or aquatic products are available. Studies on the supply response of agricultural products began to develop early. In particular, the supply response of agricultural products such as cereals and food developed by Nerlove (1958), Askari & Cummings (1977). Nerlove (1958) developed a partial adjustment supply response function in accordance with the supply theory. Since then, Nerlove supply response function has been interesting to many scientists and applied in experimental studies of food crops and non-food crops in some countries such as the US, India, Thailand, and Chile (Holt & Johnson, 1988), chicken supply in the United States (Chavas & Johnson, 1982) and the catfish industry in the US (Nguyen, 2010). Nerlove supply response function (1958) is a dynamic supply response model combined with the expected price set in the form of a self-regression model. Therefore, supply can be a function of delayed price and other factors (Tomek & Robinson, 1981). In addition, the feasibility of the experimental study of the Nerlove supply response functional depends on the structure of data and the selection of the estimation method (Baum & Christopher, 2006). Researchers need to determine the model of the expected price and data structure to determine the appropriate

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functional form. A theoretical framework gives researchers a scientific basis for choosing an approach to conduct an experimental analysis of the supply of black tiger shrimp in the Mekong Delta.

According to the evaluation of the Ministry of Agriculture and Rural Development (MARD) and functional sectors, brackish shrimp is the main aquaculture product; In 2017, the farming area is 705 thousand hectares and accounts for over 64% of the aquaculture area of the whole country. From 2010 to 2017, the value of shrimp export turnover of the whole country increased from 2.1 billion USD to 3.8 billion USD, accounting for 46.0% of the export value of the fishery sector (AgroMonitor, 2017; VASEP, 2018). Therefore, brackish shrimp is identified as a main and potential product with many advantages in development (MARD, 2015, 2017). Mekong Delta has advantages in farming, processing and exporting brackish shrimp. The area and production of black tiger shrimp in the region account for over 90% and 80% compared to the whole country, respectively. Total capacity is over 1 million tons of products per year, the number of factories accounts for over 60% compared to the whole country (MARD, 2015). The area and production of brackish water shrimp in the Mekong Delta, black tiger shrimps are cultured in 8 coastal provinces, including Long An, Tien Giang, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu, Kien Giang, and Ca Mau (AgroMonitor, 2017; VASEP, 2016). In 2015, when white leg shrimp prices dropped sharply [1]; many households switch to raising black tiger shrimp as a traditional object of high value [2]. Some provinces have a large area and the output of black tiger shrimp increased sharply. In particular, Kien Giang province increased by 11.2% in area and 15.7% in production, and Soc Trang increased by 2.8% in area and 48.1% in production. This leads to an increase of 4.0% in the area and production of black tiger shrimp in the Mekong Delta compared to 2014 (VASEP, 2015). The paper deals with analyzing the dependence of black tiger shrimp supply on shrimp price, input element prices, competitive product prices and other non-price factors affecting the supply in Mekong Delta provinces in the context of the interaction among prices in different market segments in the marketing channel and among prices over time in the market.

2. Literature review

In the past review, these models have been developed to explain the dynamics of agricultural supply, by the adaptive expectation model Nerlove (1958) and partial adjustment model Griliches (1967). Both models lead to a lag distributed model. The basic foundation of distributed lag models of agricultural supply is the farm producers make decisions based on past prices. Recently, Vector Autoregressive (VAR) models have been developed to explain the dynamics of market behavior (Bessler, 1984; Brandt & Bessler, 1984). In addition, the dynamics of supply can be more precisely investigated when considering biological haracteristics of plants and animals in the estimations. Chavas and Johnson (1982) separated U.S. broilers and turkey production into 4 stages from placement, testing, hatching, and production. Holt & Johnson (1988) also investigated the supply dynamics of different production stages in the U.S. pork industry. Cummings (1975) used the Nerlovian model to detect any interregional differences in price response for several different crops. Moreover, he suggested to fully evaluate individual production decisions, a microeconomic approach would be needed to discuss market responsiveness in terms of patterns displayed by the farmers. Output measurements are incorporated into supply response estimation in various ways, but mostly in crop weight and volume. However, acreage is a good measurement relating to the producer‘s expected price to their production decision. The time lag between planting and harvesting is an important factor in the response of output supply to price (Askari & Cummings, 1977). Since then, the Nerlovian model with many modifications has been used in a number of studies on acreage supply response of major agricultural commodities both in the developed and developing countries. Many authors have expanded their research to other survey subjects such as the catfish farming industry by Nguyen (2010), sugar cane supply by Kumawat & Prasad (2012) and aggregate agricultural output supply response in Akwa Ibom State of Nigeria (Utuk, 2014). The theoretical price models with the expected hypothesis used in Nerlove supply response analysis (1958) are estimated with the secondary data series as Cobweb expected price model hypothesis (Vo, 2004, 2011)

3. Methodology and data source

3.1 Theoretical framework

In agricultural production, due to the biological characteristics of plants and animals, the supply cannot immediately respond to price changes. Manufacturers often rely on past prices to form the expected price for the current production and thus make decisions on the production. Therefore, supply can be a function of the delayed price and other factors (Tomek & Robinson, 1981). The dynamic supply response model combined with the expected price is set in the self-regression model of Nerlove (1958) with the cultivated area (A_t), presented in the following system of equations:

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[1] *The price of white leg shrimp in the first week of June increased by 10,000-15,000 VND /kg; The second week continued to increase by 3,000-5,000 VND/kg*

[2] *At the same time, applying the model of raising black tiger shrimp with other aquatic products such as crab and perch has relatively good efficiency, increasing the ability to fight diseases.*

Supply function: $$A_t^* = \alpha_0 + \alpha_1 P_t^* + \alpha_2 Z_t + \alpha_3 T + u_t \quad (1)$$

Expected price: $$P_t^* - P_{t-1}^* = \beta(P_{t-1} - P_{t-1}^*) \quad (2)$$

Manufacturing adjustment: $$A_t - A_{t-1} = \varphi(A_t^* - A_{t-1}) \quad (3)$$

where: A_t^* is the expected area (ha); P_t^* is the expected price of the product in the period t (thousand dongs); P_{t-1}^* is the expected price of the product in the period t-1 (thousand dongs); P_t is the price of the product in the period t (thousand dongs); $A_t - A_{t-1}$ is the real change (ha); A_t^* - A_{t-1} is the expected change (ha); A_t is the area in the period t (ha); A_{t-1} is the p cultivated area in the period t-1 (ha); Z_t is the factors affecting the area of the product in period t; T is a variable that reflects the time effect; u_t is random disturbance; α_i are the intercept and slope coefficients; β is the coefficient adjusting the expected price; φ is the coefficient adjusting the production; With $0 < \varphi \leq 1$ is an adjusting coefficient. The characteristics of the agricultural sector are uncertain as imperfect price information and the limitation in knowledge and vision of farmers. According to Nerlove (1958), the expected price is a Cobweb price model with Adaptive Expectation (AE), rewritten by a lagged price model (Braulke, 1982).

$$A_t = \delta_0 + \delta_1 P_{t-1} + \delta_2 A_{t-1} + \delta_3 A_{t-2} + \delta_4 Z_t + \delta_5 Z_{t-1} + \delta_6 T + v_t \quad (4)$$

where $\delta_0 = \alpha_0\beta\varphi$; $\delta_1 = \alpha_1\beta\varphi$; $\delta_2 = [(1-\beta) + (1-\varphi)]$; $\delta_3 = -(1-\beta)(1-\varphi)$; $\delta_4 = \alpha_2\varphi$; $\delta_5 = -\alpha_2(1-\beta)\varphi$; $\delta_6 = \alpha_3\varphi$ and $v_t = \varphi(u_t - (1-\beta)u_{t-1})$. The supply elasticity determined by Braulke (1982) is calculated as follows. Short-run supply elasticity coefficient is

$$E_{SS} = \delta_1 \left(\frac{\overline{P}}{\overline{A}} \right) \quad (5)$$

and long-run supply elasticity coefficient is

$$E_{ls} = \delta_1 / (1 - \delta_2 - \delta_3) \left(\frac{\overline{P}}{\overline{A}} \right). \quad (6)$$

3.2. Estimation of supply response using Nerlovian model

The system of equations of black tiger shrimp supply responses is presented below:

$$A_{it} = \delta_0 + \delta_1 \sum_{j=0}^{2} \ln A_{it-j} + \delta_2 \sum_{j=0}^{2} \ln P_{it-j} + \delta_3 \sum_{j=0}^{2} \ln Pm_{it-j} + \delta_4 \sum_{j=0}^{2} \ln Pc_{it-j} + \delta_5 \sum_{j=0}^{2} \ln Ps_{it-j} + \lambda_{it} + v_{it} \quad (7)$$

where $\ln A_{it}$ is the black tiger shrimp farming area at the time t (ha); $\ln A_{it-j}$ the black tiger shrimp farming area at the time t-j (ha); $\ln P_{it-j}$ is the black tiger shrimp price in the original year (2010) at the time t-j (thousand Vietnamese dongs/tons); $\ln Pm_{it-j}$ is the white leg shrimp price in the original year (2010) at the time t-j (thousand Vietnamese dongs/tons); $\ln Ps_{it-j}$ is the black tiger shrimp price in the original year (2010) at the time t-j (thousand Vietnamese dongs/million post); $\ln Pc_{it-j}$ is the sea scab price in the original year (2010) at the time t-j (thousand Vietnamese dongs/ton); *i,t* are the indicators degerminating province and time of the data respectively; λ_{it} is observed factors that have a fixed effect on $\ln A_{it}$ and can be correlated with the independent variables in the model (7); v_{it} is random disturbances; δ_i is the intercept and slope coefficients.

3.3 Data collection

The two criteria of farming area and production are used as a basis for selecting research sites. According to the data of the General Statistics Office and MARD in the period of 2014-2017, Ca Mau, Kien Giang, Bac Lieu, and Soc Trang are the provinces with the largest farming area and production of black tiger shrimp in the Mekong Delta, averagely accounting for over 90.0% and 75.0% respectively compared to the farming area and production of the whole Mekong Delta. Therefore, four provinces of Ca Mau, Kien Giang, Bac Lieu, and Soc Trang were selected to represent the research site in the Mekong Delta (General-Statistics-Office, 2017; MARD, 2017). The shrimp supply response analysis model in the Mekong Delta is based on panel data from the 1st quarter of 2014 to the 4th quarter of 2017 of 4 provinces (Ca Mau, Bac Lieu, Soc Trang, and Kien Giang), with 64 observations. The data series are implemented by the Department of Statistics and the Department of Finance of the 4 provinces and unified by the functional industry before monthly publication, storage and reporting to management levels. After that, the price data series of black tiger shrimp and white leg shrimp were attributed to the actual price in 2010 before conducting the analysis.

2.5. Data analysis

The fixed Effects (FE) method and Random Effects (RE) method are used to estimate the Nerlovian supply response function adjusted according to the area (model 7). Then, the Hausman test is used to choose one amongst the two models, RE và FE, with the null hypothesis H_0, that the estimated coefficient of RE and FE is undifferentiated (Hausman, 1978). If P-value is less than 0.05, H_0 will be rejected. Rejecting H_0 implies that the FE estimation results will be more appropriate (Baum & Christopher, 2006).

3. Empirical results

3.1 Relationship between farm-gate price and area and output of black tiger shrimp through time in Mekong Delta

The statistical data is presented in Fig. 1, shows the evolution of the farm gate price of black tiger shrimp corresponding with black tiger shrimp farming area from the first quarter of 2014 to the fourth quarter of 2017 in 4 provinces - Bac Lieu (*baclieu*), Kien Giang (*kiengiang*), Soc Trang (*soctrang*) and Ca Mau (*camau*), which the largest area in Ca Mau, Bac Lieu, and Kien Giang, accounting for over 86% of the area of black tiger shrimp farming in the whole Mekong Delta.

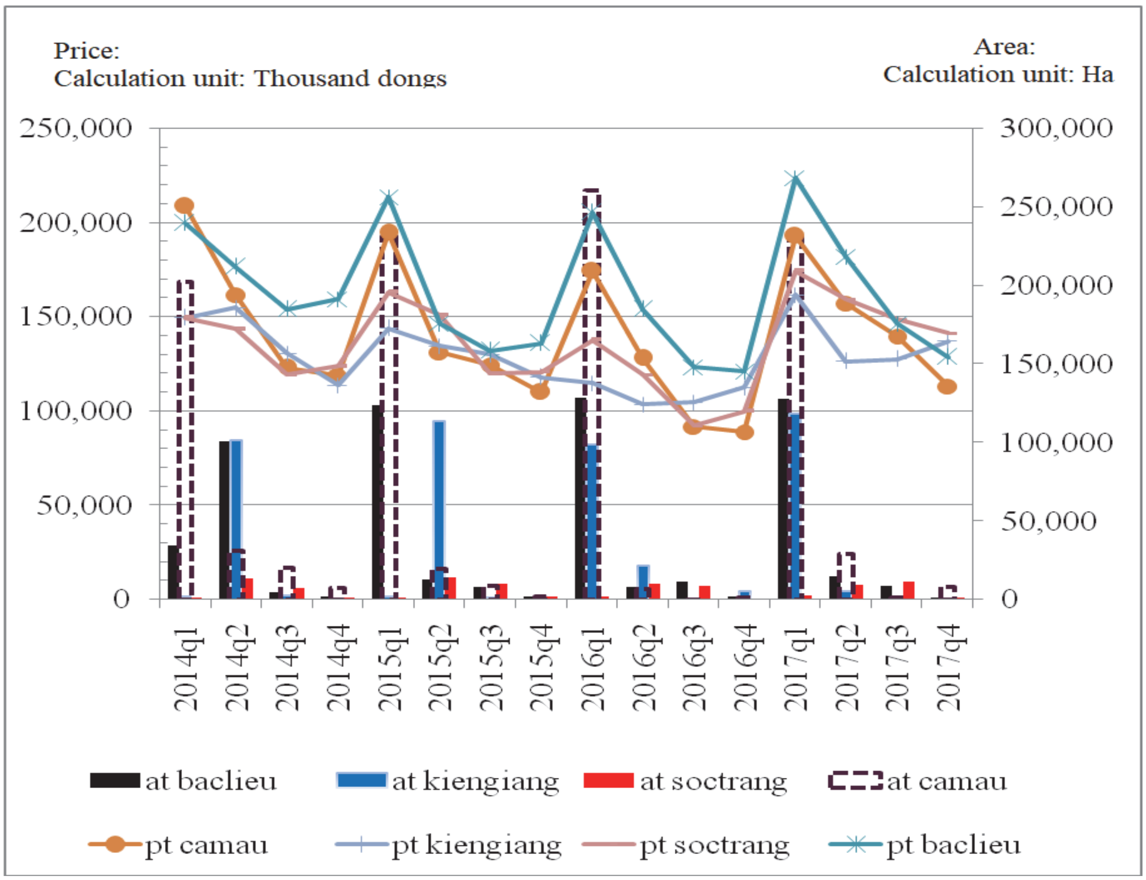

Fig. 1. Area and price of black tiger shrimp through time

Source: General-Statistics-Office and MARD, 2017

The area of black tiger shrimp farming is largest in the first quarter of the year when the price of black tiger shrimp reaches the highest point. In the second quarter, the farming area and price of shrimp tend to decrease and bottom in the third quarter and then rise again in the fourth quarter and peak in the first quarter of the next year. This shows that, in the provinces surveyed, farmers decided on the area of black tiger shrimp farming based on the adjustment of selling price in the year. According to economic theory, the farmers' decision to adjust the farming area is not effective due to the delay of 4-5 months between the time of stocking and harvesting black tiger shrimp. The reason is that black tiger shrimp are mainly cultured under the improved extensive model, combined with rice, forest, and other aquatic species, accounting for over 64% of the whole area of brackish shrimp farming in the region. This model of production depends largely on nature and the distribution is not uniform between the quarters of the year. To better understand this adjustment, the author continues to analyze the relationship between the price and output during this period.

3.2. Descriptive statistics and stationarily test of the panel data

Table 1 presents the descriptive statistics of the price variables of black tiger shrimp. The standard deviation of the variables is relatively small, indicating minor price fluctuations between periods. The price series in the survey period is stationary at the original series with a 5% statistical significance level (Im, Pesaran, & Shin, 2003). Therefore, price data series satisfy the conditions for quantitative analysis by FE and RE estimates (Table 2).

Table 1
Descriptive statistics of log-transformed variables in the supply function

Variable	Obs	Average	Max	Min	Standard deviation
$\ln A_{it}$	64	8.74	12.47	4.93	1.93
$\ln Am_{it}$	64	6.87	9.89	0.00	1.61
$\ln P_{it}$	64	11.8 9	12.50	11.39	0.25
$\ln Pm_{it}$	64	11.25	11.85	10.87	0.20
$\ln Pst_{it}$	64	10.60	11.28	10.06	0.28
$\ln Pc_{it}$	64	11.62	12.19	1066	0.36

Source: Summarized of test results *Note: **, *** corresponds to statistical significance of 5% and 1% respectively*

Tables 2
Test of the unit root of black tiger shrimp price panel data

Variables	Variables name	Static	P -Value
$\ln A_{it}$	Black tiger shrimp farming area	- 5.066 ***	0.000
$\ln Am_{it}$	Whiteleg shrimp farming area	- 6.647 ***	0.000
$\ln P_{it}$	Farm-gate price of black tiger shrimp	- 3.303 ***	0.000
$\ln Pm_{it}$	Farm-gate price of white leg shrimp	- 5.385 ***	0.000
$\ln Pst_{it}$	Farm-gate price of black tiger shrimp seed	-2.570 ***	0.005
$\ln Pc_{it}$	Farm-gate price of mud crabs	-1.902 **	0.029

Source: Summarized from the test results of the survey panel data
*Notes: **, *** corresponds to statistical significance of 5% and 1% respectively.*

3.3. Estimation of supply response model of black tiger shrimp

The estimation results of the Nerlove supply response function of black tiger shrimp in the Mekong Delta, which is adjusted based on the output using FE and RE, are presented in Table 3. The level of significance of the Hausman test with P_value <0.05 implies that the FE is appropriate and the model has no serial correlation. However, the Nerlove supply response function by output is violated in terms of the assumption of heteroscedasticity so the author adjusted by the model with robust standard error. This means that the estimation results by FE are reliable. Short-run estimation of the supply response model shows that the late price of the previous season affects the decision to adjust the farming area positively and strongly (Askari & Cummings, 1977). This is the evidence that the black tiger shrimp farming area in the provinces surveyed is very sensitive to the impact of the farm-gate price of the products in the season. This implies that farmers quickly update the information when establishing expected prices in the process of adjusting the supply of black tiger shrimp by expanding the shrimp farming area to increase the output of black tiger shrimp both in the short-run and long-run. Therefore, it is necessary to have policies to improve the capacity and market access of the farmers based on each group of producers.

3.4. Coefficient of supply elasticity in farming area

The coefficients of supply elasticity by output with farm-gate price of the product, farm-gate prices of input elements, and farm-gate prices of competitive products are elastic (Table 4). Low productivity and the application of science and technology in black tiger shrimp farming are the causes of the insignificant adjustment of black tiger shrimp supply when facing the impact of its own farm-gate price, input element farm-gate prices and competitive product farm-gate price in short-run. Therefore, it is necessary to have breakthrough policies on technical, scientific, and technological solutions in the improved extensive black tiger shrimp farming area.

Table 3
The estimation results of Nerlovian production area response

Variable name	Variables	FE	RE
ln (black tiger shrimp farming area in the quarter t-1)	$\ln A_{it-1}$	-0,32** (-2,38)	-0,19 (-1,36)
ln (black tiger shrimp farming area in the quarter t-2)	$\ln A_{it-2}$	-0,68*** (-4,89)	-0,49*** (-3,24)
ln (black tiger shrimp price in the quarter t-1)	$\ln P_{it-1}$	2,72* (1,88)	2,66* (1,75)
ln (black tiger shrimp price in the quarter t-2)	$\ln P_{it-2}$	2,65 (1,50)	2,63 (1,55)
ln (white leg shrimp price in the quarter t-1)	$\ln Pm_{it-1}$	-3,81** (-2,48)	-4,22** (-2,39)
ln (white leg shrimp price in the quarter t-2)	$\ln Pm_{it-2}$	3,50** (2,2)	2,01 (1,30)
ln (mud crab price in the quarter t-2)	$\ln Pct_{it-2}$	-2,81*** (-3,31)	-3,13*** (-3,30)
ln (black tiger shrimp seed price in the quarter t)	$\ln Pst_{it}$	1,32 (1,61)	1,46 (1,57)
ln (black tiger shrimp seed price in the quarter t-2)	$\ln Pst_{it-2}$	-3,03*** (-3,50)	-2,73*** (-2,98)
Constant	c	7,97 (0,35)	26,51 (1,35)
R^2		0,57	0,52
Wald statistic (χ^2 value)		6,44	36,00
Level of significance (Prob> χ^2)		0,00	0,00
Hausman statistic (χ^2 value)		71,75	
Level of significance (p-value)		0,00	
Modified Wald test (χ^2 value)		5,48	
Level of significance (Prob> χ^2)		0,24	
Lagrange Multiplier Test		6,42	
Level of significance (Prob>F)		0,09	

*Note: *, *** corresponds to statistical significance of 5% and 1% respectively*

Source: Summarized of estimated results in the researched provinces

The estimated results of the supply response model in terms of the farming area have an impact on black tiger shrimp area and output in the current quarter (Nguyen, 2010). The estimated results show that the supply adjustment is affected by the prices of black tiger shrimp, of the competitive products, and input elements in accordance with supply law.

Table 4
Supply elasticity in short-run

Variable name	Variable	Area
Black tiger shrimp price in the quarter t-1	εP_{it-1}	2,72
Black tiger shrimp price in the quarter t-2	εP_{it-2}	2,65
White leg shrimp price in the quarter t-1	εPm_{it}	-3,81
White leg shrimp price in the quarter t-2	εPm_{it-2}	3,50
Mud crab price in the quarter t-2	εPc_{it-2}	-2,82
Black tiger shrimp seed price in the quarter t	εPs_{it}	1,32
Black tiger shrimp seed price in the quarter t-2	εPs_{it-2}	-3,04

Source: Summarized and calculated in the researched provinces

As a result, that commercialization has a greater positive impact on the expansion of area than on the increase of the output of black tiger shrimp in the researched provinces in the Mekong Delta (Learn & Cochrane, 1961). This implies that black tiger shrimp farming in the researched provinces in the Mekong Delta is being adjusted by farmers based on the selling prices of the product itself and of the competitive products. However, the elasticity coefficient of these factors in the short-run is greater than in the long-run (Tables 4 and 5). Analysis results showed that black tiger shrimp farming in the researched provinces in the Mekong Delta is not yet stable.

Table 5
Supply elasticity in long-run

Variable name	**Variable**	Area
Black tiger shrimp price	εP_{it}	2,68
White leg shrimp price	εPm_{it}	-0,15
Mud crab price	εPc_{it}	-1,40
Black tiger shrimp seed price	εPs_{it}	-0,85

Source: Summarized and calculated in the researched provinces

4. Discussion and Conclusions

The study has used the FE estimation method for analyzing the reaction function of Nerlove supply of black tiger shrimp in the Mekong Delta; with the late area variable (quarter t-1 and t-2) of the previous season, the negative correlation with the variable area of tiger shrimp farming of the current crop. This means that farmers who increase the area of previous tiger shrimp farming are the factors that increase the supply to the market, the current area of black tiger shrimp farming will decrease, leading to a reduction in supply to the market and vice versa. At the same time, farm production decisions are related to competitive products and farming techniques. In the short and long term, the coefficient of supply elasticity of output at the farm gate price of the product, the gate price of the farm of inputs and the price of the competitive farm gate (mud crab) are elastic. However, the coefficient of elasticity of output supply with the price of the farm gate of the competitive product (White leg shrimp) is elastic. Meanwhile, the elasticity of supply in terms of the farm gate price of the product, the price of the farm gate of the input factor and the price of the farm gate of the competitive product are elastic. This shows that the area of tiger prawn farming is very sensitive before the price fluctuation of the previous crop. The supply of black tiger shrimp moved to the left before the impact of the increase in the price of tiger shrimp and competitive product prices. Based on the research results, suggested policy suggestions are as follows:

(1) The price of the previous crop is the expected price which is the basis for farmers to decide the area of shrimp farming, later than the actual price, so the supply is also lagging compared to the demand in the market. Therefore, timely price forecasting and dissemination of price information have positive implications in timely supply adjustment.

(2) Through analysis, results show the heavy dependence of this industry on nature. Therefore, it is necessary to have policies to improve capacity, market access, and production awareness to protect the environment and natural resources of shrimp farmers.

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