Fishery Resources Sustainability Assessment Model

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Abstract

The aim of this study is to build a model of the fishing market, which can be used to assess the sustainability of fishery resources through the resulting indicators. The model uses four equations that make up the system of simultaneous equations, the demand side and the supply side. Sustainability indicators assessed from the interplay of endogenous variables and lagged endogenous variable. The model was applied to the unique fisheries of Aceh, which consists of two areas of marine ecosystems; therefore, it is necessary to include abundance of market variables and also consider the possibility of market imbalance. The results of model estimation indicate that the Malacca Strait fishery areas have experienced excessive exploitation Fisheries resources and begin to interfere with the growth of the stock. Moreover, the result of the study also illustrated the declining the number of stocks, while the utilization in the Indian Ocean are around the Maximum Sustainable Yield.

Keywords: Sustainable, capture fisheries.

1. Introduction

A marine fishery resource is one of renewable resources with strategic value for sustainable development efforts. Whereas, the potential of sustainable conservation and utilization can be interpreted as the optimal amount for consumption in a given period without reducing the optimal number of possible consumption in the future periods. In this case, there are at least two factors to be considered, the reproduction ability and the consumption possible number. (Bischi, Kopel, & Szidarovszky, 2005) state that the dynamics of fish stocks is influenced by two factors. First, the ability of fish population to recover, referring to the ability of fish to reproduce over time. And second, the declining number of fish stocks due to fishing activities. Hence, the sustainability of fish resources is determined by the magnitude of the amount that can be consumed and the amount that omitted for future periods.

The existence of marine fishery resources has become an increasingly important role in the economy, particularly in the provision of employment, food needs, improving the living standard as well as a foreign exchange resource. Fishery also provides a livelihood to the majority of coastal communities. (Cho, 1996) reports, coastal fishery has two important roles, as the main source of income for small scale fishing for subsistence household and as a provider of high quality food source for domestic consumption.

The estimation results of the FAO states that the contribution of fish to meet the needs of animal protein reaches more than 25% of the total animal protein needs of the Asian community (Briones, Garces, & Ahmed, 2005)

As the sustainable resource and the common good, fish stock is highly dynamic. The stock amount is possible to thin out due to over exploitation and it may threaten the sustainability. On the other hand, the fisheries resource is highly potential to be sustainably utilized, by preserving the reproduction over time. However, total population of fish in the sea is difficult to estimate with certainty. Therefore the amount that can be taken at this time and the amount is left for the next period cannot be determined. The most important factor is to know the indicators that can provide clues about the sustainability of the fish catch and ensuring that the management policies are not misdirected.

Constructing a model of fishery resources that can provide indicators and guidance to assess the condition and determine the status of sustainability as a basis for policy making in fisheries management is crucial. Determining the appropriate level of fish catch and the factors that influence it is vital to maintain the sustainability of fish resources while avoiding the economic loss is one of the examples. Trinidad in (Briones, Garces, & Ahmed, 2005) estimate the loss of economic rents in the Philippines due to excess fishing effort is above 30 percent, sustainable economic rent will result in a loss of U.S. $ 145 million per year. One of the leading factor is the use of fishing tools to catch more than necessary. (Joseph, Squire, Bayliff, & Groves, 2006) and (Greboval & Munro, 1999) estimates that in the last 30 years, the increasing activity of fishing boats are faster than the catching result.

2. Data and Methodology

This study attempts to build a fisheries markets model which is applied to Aceh fishing market. The constructed model has three equations which makes up the supply-side behavior, and one equation on the demand side. The unique fishery conditions in Aceh has two fishery management area. Those are included as a market imbalance variable and a variable abundance of market on the supply side.

The behviours of the demand function is described as;

$$D_t = \rho_0 + \rho_1 P_t + \rho_2 SP_t + \rho_3 Y_t^2 + \rho_4 POP_t + \rho_5 IP_t - \rho_6 D_{t-1} + e_1 \quad (1)$$

Wherein, a demand function (D_t) constructed by inserting a price variable (P_t), a price of substitute goods (SP_t), the square of income (Y_t), a population of POP_t, and lag demand. A IP_t variable is an increase price index $\Delta P_t > 0$) to accommodate the possibility of imbalance. While the supply function is described by three equations, namely;

$$S_t = \delta_0 + \delta_1 P_t + \delta_2 E_t + \delta_3 E_t^2 + \delta_4 X_t + \delta_5 X_t^2 + \delta_6 DP_t + \delta_7 W_{ijt} + \delta_8 S_{t-1} + e_2 \quad (2)$$

$$X_t = k_0 + k_1 E_t + k_2 P_t + k_3 D_t + k_4 X_{t-1} + e_3 \quad (3)$$

$$E_t = c_0 + c_1 C_t + c_2 L_t + c_3 E_{t-1} + e_4 \quad (4)$$

Where; a supply function (S_t) , is a function of price (P_t) , fishing effort (E_t) is assumed to be quadratic since the beginning of the increasing period, the fishing effort may improve the offer. However, at the some point the increase of the amount of fishing effort is not balance with the increasing of supply or even the offer are decrease. In addition, The offer can be influenced by the number (X_t) , The DP_t variable is a decreasing price index $\Delta P_t < 0$) which accommodating the possibility of an imbalance on the supply side. In addition, the W_{ij} is a variable of abundance of market (spill over) from Malacca Strait market to Indian Ocean market and vice versa, which is illustrate the possibility of interaction between the two regions fisheries . When bidding on a site exceeds the demand , then the fish will be taken to other locations.

While the stock variable is used as an endogenous variable which is functionally affected by several other variables , such as fishing effort and the number of requests and the price of fish , as well as the lag stock of one year. If the number of requests increases , the stock will be under pressure due to increased exploitation . Fish stock growth function is a function of density dependent growth , which means that the growth dynamics of fish stocks is determined by the number of stocks in the previous period , and human intervention . While the function of fishing effort is also treated as an endogenous variable . Fishing effort is functionally affected by the amount of operating expenses arrest (C) , when the high operational costs fishermen may rest the fleet or reduce the number of trips . Gain (L) , when gain on the fisheries industry is high, then a lot of people who entered to this sector , or increase trip as a short-term response , however, the response would require the addition of a fleet of ships depicted with a lag time of one year fishing effort.

The fourth function is the transformation structural equations 1,2,3, and 4 above can be written in a reduced model of the following form;

$$\Omega Z_t = \Psi Z_{t-1} + \Phi V_t + e \quad (5)$$

$$Z_t = \Omega^{-1}\Psi Z_{t-1} + \Omega^{-1}\Phi V_t + \Omega^{-1}e \quad (6)$$

where; $\boldsymbol{\Omega}$ is a endogenous variable parameter matrix, Z_t a endogenous variable matrix, Ψ is Parameter matrix of lag endogenous variable.

$$\Omega = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & -\delta_4 & -\delta_2 \\ -k_3 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix};\ Z_t = \begin{bmatrix} D_t \\ S_t \\ X_t \\ E_t \end{bmatrix};\ \Psi = \begin{bmatrix} \rho_6 & 0 & 0 & 0 \\ 0 & \delta_8 & 0 & 0 \\ 0 & 0 & k_4 & 0 \\ 0 & 0 & 0 & c_3 \end{bmatrix};\ Z_{t-1} = \begin{bmatrix} D_{t-1} \\ S_{t-1} \\ X_{t-1} \\ E_{t-1} \end{bmatrix}$$

Φ exogenous variables parameter matrix, V_t is a matrix of exogenous variable, and e is an error term matrix;

$$\Phi = \begin{bmatrix} \rho_1 & \rho_2 & \rho_3 & \rho_4 & \rho_5 & 0 & 0 & 0 & 0 & 0 & 0 & \rho_0 \\ \delta_1 & 0 & 0 & 0 & 0 & \delta_3 & \delta_5 & \delta_6 & \delta_7 & 0 & 0 & \delta_0 \\ k_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & k_0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & c_1 & c_2 & c_0 \end{bmatrix}; V_t = \begin{bmatrix} P_t \\ SP_t \\ Y_t^2 \\ POP_t \\ IP_t \\ E_t^2 \\ X_t^2 \\ DP_t \\ W_t \\ C_t \\ L_t \\ 1 \end{bmatrix}; e = \begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \end{bmatrix}$$

This model turns out to have an endogenous variable parameters matrix which is not a triangular matrix, it shows that this model can be estimated with a two-stage method or 2SLS. The variable which is not stationary transformed using differencing.

The short run multiplier effects are denoted as H_1 and H_2 while the long run multiplier effect is denoted as H_3 which formulated as follow (Reutlingler, 1996).

$$H_1 = \Omega^{-1}* \quad (7)$$
$$H_2 = \Omega^{-1} *\Phi \quad (8)$$
$$H_3 = (1- H_1)^{-1} * H_2 \quad (9)$$

The data used in this study are secondary data published in the Department of Marine and Fishery in 1989 – 2010 periods, and also cross section data which is the operational cost of fishing.

3. Findings and Discussion

Fish is an important commodity in the consumption of Acehnese society, even a staple food in the diet than rice, is shown by the prominence is not the price (P_t) against the demand for fish. There is no substitute product that can replace the function of the fish in their daily diet, not even chicken (SP_t).This is true on both the demand for fish fishery areas.(Table 1)

In the Malacca Strait fishery market, rising prices index variable (IP_t) marked negative and significant, according to the equation (1) shows the response of demand tends to increase when the price crept up, this condition does not occur in the Indian Ocean fisheries market. It is an indicator of long-term imbalances in the Malacca Strait fishery market, due to the pressure of demand, while the supply is not able to respond quickly. IP_t index coefficient is-0.00422 this indicates that the market cannot make adjustments in the short term to bring supply and demand in a new equilibrium. While the Indian Ocean fisheries markets, the assumption is not supported by the fact DP_t price index decreased significantly but is negative, the total effect on supply is the supply increases as the price falls, it indicates that there is no market imbalance. In the Indian Ocean fishing areas, the index price reduction (DP_t) is positive and significant. By equation (2) can be interpreted that response also offers downhill when prices fall, meaning there is no indication of an imbalance in the market in the region.

Variable quadratic income effect on demand and marked negative but the coefficient is relatively small, while the population variable coefficients greater mean change in demand is more influenced by the population of the increased revenue. In the early period of rising incomes, demand for fish increased slightly but once it reaches a certain point demand response actually decreases when income changes increases. It can be explained that if the change in people's income increases, the percentage share of their income is used to consume the smaller fish though nominal amount used to eat fish did not change. In addition, there is the tendency to diversify the diet. When income increases Aceh people will consume high-quality fish and combine diet with other foods, as a supplement.

Coefficient of income elasticity of demand is low, or less than 1, indicating that the fish is a commodity that is needed by the people of Aceh, as a source of animal protein fulfillment. Acehnese society in general especially in rural areas prefers vegetables or fish from the other menu. So the fish can be classified as essential goods. Waterway demand growth faster than the Indian Ocean which is shown by the partial adjustment coefficient respectively 0.51335 and 0.23019.

Similarly, the demand function, supply function in both regions was also not affected by the price of fish. Variable fishing effort showed different effects on the two fishing areas. In the Malacca Strait fishery offers response (the catch) began to decline to the increased effort. This indication is shown by the significant quadratic variable fishing effort and marked negative. This indication shows that fishing effort is put into operation in the Malacca Strait fishery is over capacity. This is in line with the bids marked lag variable negative, this means an indication of change in the number of deals and tend to fluctuate from year to decline this condition has not occurred in the Indian Ocean fisheries, which is indicated by the square of the variable is not significant undertakings of the arrest and the lag offer is positive.

Table 1. Estimation Results of Model

Variables	Malacca Strait region				Indian Ocean region			
	Demand	Supply	Stock	Effort	Demand	Supply	stock	Effort
const	33559.8 *	1625.4	26 831 *	94 558	9276.4	22754 *	-6586.9	76.2058
P_t	0.002283	0.00031	-0.000176		-0.00024	0.00024	-0.0010 *	
SP_t	0.000346				-0.000177			
Y^2_t	-1.63E-5 *				-7.72 E-6 *			
POP_t	0.100717 *				0.1194 *			
D_t			-0.4226 *				0.17296	
D_{t-1}	0.486645 *				0.769809 *			
IP_t	-0.00422 *				-0.000691			
E_t		29,881 *	-11.5297 *			6.19971 *	-14 977 *	
E_t^2		-0.0017 *				0.000586		
X_t		3.8502 *				1.73995 *		
X^2_t		-2.9E-5 *				-1.21E-5 *		
W_{IJT}		-0.1002				-0.07677		
DP_t		-0.00071				-0.01587 *		
S_{t-1}		-0.4055 *				0.546642 *		
X_{t-1}			0.19633 *				-0.4454 *	
C_t				-0.00127 *				-0.00067 *
L_t				5.87E-5				0.00022 *
E_{t-1}				-0.3151 *				0.02719
R^2	0513	0872	0792	0172	0559	0755	0502	0304

Sources: 2SLS estimation results
Note: * = significant

Variables influence the direction the stock is positive and the stock is negative squares, and in both regions have the same effect, but the coefficient is greater in the Malacca Strait fishery, meaning that the growth rate of the stock in the two regions began to decline and the decline was more pronounced in the area of the Strait of Malacca.

Theoretically, the amount of fish that can be offered or the amount of the catch, at least depends on two factors: the amount of fish that can be caught and given the level of effort (Briones.RM, 2006).If the number of larger fish at the abundance of the stock decreases in a subsequent period, but due to great efforts to arrest the catches also increased. This condition is different from the Malacca Strait fishery performance where increased efforts are not followed by a steady increase in the catch.

Demand for fish is affecting the reduction of fish stocks in the Straits of Malacca and had no effect on the Indian Ocean fisheries. This is very related to the magnitude of the waterway request, as long as the fish are caught by fishermen still are asking, then the fishermen or fishing companies will try to meet that demand, by enabling fleet. If demand is greater, to increase the number of fishing opportunities the number of fishing trips also large enough so that the effect reducing stock. Growth of fish stocks are indicated on the trend continues to decline and could threaten the sustainability of fishery resources in the Straits of Malacca as indicated by the positive sign of the variable lag stock but give a negative effect on the supply function. It means that a positive relationship should be interpreted the smaller growth this year will be smaller growth in the next cope.

Variable lag while the Indian Ocean fish stocks are negative, which means that growth stocks fluctuated. If the high growth period of last year, this year will be low, the fish began to slow regeneration ability. Besides the price variable negative influence on the supply or the catch, fishing during high price so the stock can reproduce trip decreases with increased effort. Function of fishing effort in the Indian Ocean fisheries are still influenced by the variable gain, and fishing effort showed a slight tendency to increase, which lag variable is positive but not significant effort. While in the Malacca Strait has no effect on the gain factor of fishing effort, this means a decrease in the number of fish stocks led to increasingly difficult to catch fish and increase the cost of eroding profits of fishermen. Lag fishing effort marked a significant negative growth efforts tend to fluctuate, meaning that when the cost increases, the fishing fleet that enable less effort decreases and vice versa.

Alleged that the two markets interact with each other through the overflow of the market was strong enough not supported by statistics. Overflow variable (Wij) is not significant in both fishing areas, an abundance of market possibilities besides the Indian Ocean brought to the market in the Strait of Malacca is also marketed to the outside Aceh or in exports. But exports have not been included variables included in the model.

3.1 Dynamic Multiplier

The simultaneously short-term effect of exogenous variables on the endogenous variables is the matrix elements of H2 in equation (8). The estimation results indicated that the short-term effect of the population variable and gains of growth stocks of the Indian Ocean is positive, which means people do not put pressure on the stock, while catching affordability is still beyond decreased growth stocks. This condition is different from the Straits of Malacca, where the second variable is indicated a negative effects.

Table 2. The short term effect of the exogenous variable

V	SP_t	P_t	Yt^2	POP_t	DP_t	IP_t	W_t	C_t	L_t
Xt	-0.00025 -12E-4	-0.000176 -0.0010	0.6145 -0.761	-0.037 0.1041	0	-0.0011 0.00303	0	0.0015 797E-2	-0.00031 298E-3
QS_t	0.000068 -73E-5	0.00031 0.00024	-0.164 -0.457	0.0099 0.0626	-0.00071 -0.01587	0.0003 -0.000691	-0.1002 -0.07677	0.0009 -713E-3	-0.00019 267E-3
QD_t	0.000346 -0.000177	0.002283 -0.00024	-1.63E-5 -7.72 E-6	0.10072 0.1194	0	-0.00422 -0.0006	0	0	0
E_t	0	0	0	0	0	0	0	-0.00127 -0.00067	5.87E-5 0.00022

Note: The first line number in each cell is the coefficient number of India Ocean while the second line number is the coefficient of Malacca Straits

However, there is a change in the gain variable of the Indian Ocean in the long term (Table 3). Indicating, in the long term the increasing profit will put pressure on the declining growth stocks. If the fish resources continue to be exploited, then the stock could reach the same condition as Malacca Strait nowadays.

Table 3. The long term effects of the exogenous variable

V	SP_t	P_t	Y_t	POP_t	DP_t	IP_t	W_t	C_t	L_t
X_t	-487E-4 -235E-4	-128E-3 -574E-3	1.175 -1.469	-701E-2 0.20115	0	-217E-3 5847E-3	0	331E-3 5392E-3	-690E-4 -202E-3
S_t	713E-5 -112E-3	513E-4 474E-2	-0.172 -6.97	103E-2 0.95427	-966E-4 -128E-2	317E-4 277E-2	0,369 -2.76	884E-4 - 634E-2	-184E-4 -237E-2
D_t	141E-3 -346E-4	267E-3 -949E-3	-3,407 -2.16	0,203 0.295	0	628E-3 859E-3	0	0	0
E_t	0	0	0	0	0	0	0	-253E-3 -592E-4	527E-4 221E-4

Note: The first line number in each cell is the coefficient number of Indian Ocean while the second line number is the coefficient of Malacca Straits

The long term IP_t variables are positive for both fishery regions variable while the DP_t is negative. Indicating both long-term markets will again reach equilibrium at lower stock levels. Market equilibrium in the Malacca Strait may also be possible due to the effect of the overflow of the Indian Ocean, which shows a positive sign in the long run.

Notion that the level of utilization of fish resources in the Malacca Strait and the coast of Aceh province on the Indian Ocean above MSY position and lead to a decline in fish stocks, can be analyzed through the indications shown in Table 2: it can be concluded that the status of the utilization of fish in the Malacca Strait has exceeded sustainable levels and the abundance of the stock began to decline (Table 2). Although fishing effort increased but the effect is proportional to the decrease in the size of the stock so that the amount of the catch continued to decline. By applying the theoretical concepts developed by (Ling & Milner-Gulland, Assessment of Sustainability of Bushmeat Hunting Based on Dynamic Bioeconomic Models., 2006) the status of the utilization of fishery resources in the Straits of Malacca has been at the stage where the condition of fish stocks, has started to decrease and growth of fish are in the mid stages of growth decreased *(middle of decline)* has exceeded the capacity of fishing effort. This condition leads to declining profits and threatens the sustainability of the fish catch rate.

Table 4. Description of Analysis Results Endogenous Variables in Model

No.	Strait of Malacca	Indian Ocean
1	Demand continues to increase, and the pressure is strong enough demand so that the market is experiencing imbalances	Demand continues to increase, but the market is in equilibrium
2	E^2 negative and significant to offer, E_{t-1} negative and significant is not significant to the effort. There has been an effort to capture excess	E^2 positive not significant to offer, E_{t-1} are not significant a positive and significant impact on the change effort. Yet there is excess fishing effort
3	X^2 negative and significant to offer, X_{t-1} positive and significant. Stock began to decline	X^2 negative and significant to offer, X_{t-1} negative and significant. Stock grows at the rate started to decrease and tends to fluctuate.
4	S_{t-1} negative and significant. Growth in supply or fluctuating catches or unstable	S_{t-1} positive and significant. Offers growth tends to increase.

Status Indian Ocean fishery resource use can be concluded that although growth stocks at the level of the growth rate began to decline, but large enough capacity and fishing effort exceeds the effect of decreasing the stock, so the catch was still rising. On the other hand, the sustainability utilization of fishery resources resulting in the early stages of declining growth stocks *(early stage of decline).* In other words, the fish stocks are still growing but the growth is declining. Fishing effort indicated no excess capacity. Gains may still be improved in order to achieve maximum benefit.

4. Conclusion and Policy Recommendation

There is a market imbalance in the Malacca Strait fishery, which is due to pressure on the demand side. While the Indian Ocean market is in equilibrium. The level utilization of fish resources in the Malacca Strait fishery is above MSY and are at state of decreasing of fish stocks and threatens the sustainability of the production level. While the utilization rate of the Indian Ocean fisheries resources will be around MSY but still in the early growth stock with a decreasing rate, especially near shore fisheries. Sustainability level of production can still take place, with good management of fishing effort. Should be considered to improve the regeneration of stocks, primarily through the availability of sea ecosystem allowing fish growth can be maintained.

Fishing effort in the Malacca Strait has exceeded capacity, and if there is additional fishing effort will take the market away from equilibrium, due to depleted stocks, and stocks will continue to decrease. Therefore, that sort of policy is required licensing moratorium fishing vessels. Indian Ocean fishing effort showed no excess capacity.

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