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To cite this article: Ria Dhotul Ilmiah and Siskarossa Ika Oktora 2021 *J. Phys.: Conf. Ser.* **2123** 012011

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ARIMA Intervention Model for Measuring the Impact of the Lobster Seeds Fishing and Export Ban Policy on the Indonesian Lobster Export

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Abstract. An intervention model is an analytical method for evaluating or measuring the impact of an external event called intervention, such as a natural disaster, holidays, sales promotions, and other policy changes. Two types of intervention variables will be used to represent the presence or absence of the event, i.e., a pulse or step. The pulse function is used to represent a temporary intervention, whereas the step function shows a long-term intervention. This study aims to develop a time series model with an intervention of step function for measuring the impact of two policies related to the prohibition of fishing and the export of lobster seeds on the export value of Indonesian lobster. These policies are the Ministerial Regulation No.1 of 2015 since January 2015 related banning of lobster seeds fishing (called first intervention) and the Ministerial Regulation No. 56 of 2016 since January 2017 related lobster seeds fishing and export ban policy (called second intervention). These regulations are designed to ensure lobster sustainability and add value to lobsters that are currently overfished. The results show that both policies significantly affect the export value of lobster in Indonesia, and the interventions have a permanent impact.

Keywords: Intervention model, lobster seeds, export

1. Introduction

Intervention analysis is a popular tool in economics. The main goal of this study is to determine the magnitude of the impact of an external event or intervention that can modify the pattern of time series data [1]. Two types of intervention variables that must be employed are the pulse and step function [2]. The pulse function represents temporary or transient interventions such as sales promotions, natural disasters, terrorist attacks, and etcetera. The impact of a pulse function intervention may be felt only at the time of intervention or may exist in the subsequent period. Meanwhile, the step function represents a long-term intervention, such as government or company policies. The impact of this type of intervention may remain constant over time, gradually decrease or increase, and decrease or increase linearly without bound.

Step function intervention analysis is commonly known to measure the impact of government policies on a country's import and export, such as the impact of anti-dumping regulations on US wooden bedroom furniture imports from China [3], policy impact air pollution prevention and control action, and zero percent import tariffs on coal exports of Indonesia to China [4], and the impact of anti-dumping policies on Indonesian iron imports [5]. This research focuses on the application of time series analysis,



specifically ARIMA step function intervention, to account for the impact of the Ministerial Regulation No.1 of 2015 since January 2015 related banning of lobster seeds fishing (called first intervention) and the Ministerial Regulation No. 56 of 2016 since January 2017 related lobster seeds fishing and export ban policy (called second intervention). These policies are an attempt by the government to regulate overfished lobsters (*Panulirus spp.*) resources. These policies aim to preserve the stock and long-term viability of commodities that play a significant role in Indonesia's fishery export [6]. Furthermore, these regulations strive to improve the added value of lobster seeds, which are cheaper than lobster for consumption purposes [7]. The data for this study were collected monthly from January 2012 to April 2020 by the Central Bureau of Statistics (BPS). The period was chosen based on the increasing lobster seeds export [8] and the timeframe of these regulations' implementation.

2. Statistical model

2.1. ARIMA intervention model

An intervention is a disturbance in the data pattern caused by an external event that influences the time series data [1]. Intervention analysis can be used to examine disturbances in this data pattern. Intervention analysis is a time-series data analysis used to evaluate and measure the intervention's impact. The general model with multiple interventions is as written follows

$$Y_t = c + \sum_{j=1}^k \frac{\omega_{sj(B)}B^{bj}}{\delta_{rj(B)}} I_{jt} + \frac{\theta(B)}{\phi(B)} \varepsilon_t, \tag{1}$$

then, $\omega_s(B)$ and $\delta_r(B)$ are defined as

$$\omega_s(B) = \omega_0 - \omega_1 B - \omega_2 B^2 - \dots - \omega_s B^s, \tag{2}$$

$$\delta_r(B) = 1 - \delta_1 B - \delta_2 B^2 - \dots - \delta_r B^r, \tag{3}$$

where

- Y_t : response variable in period t,
- c : constant,
- I_{jt} : intervention variable j in period t,
- j : the number of interventions,
j = 1, 2, 3, ..., k,
- $\omega_s(B)B^b$: parameters of b and s,
- $\delta_r(B)$: parameters of r,
- $\frac{\theta(B)}{\phi(B)} \varepsilon_t$: ARIMA pre-intervention model.

There are two common types of intervention variables, i.e., the pulse and step function [1]. The pulse function is an intervention taking place at only one period and does not continue. The pulse function may be written as in the following way

$$I_t = P_t^{(T)} = \begin{cases} 0, & t \neq T \\ 1, & t = T. \end{cases} \tag{4}$$

While the step function is an intervention occurring at the time T that remains in effect subsequently. Thus, the step function is denoted as

$$I_t = S_t^{(T)} = \begin{cases} 0, & t < T \\ 1, & t \geq T, \end{cases} \tag{5}$$

where t is the research time, and the intervention starts at T .

2.2. The procedure of building the ARIMA intervention model

The procedure for developing an ARIMA intervention model is outlined below [9,10,11] :

2.2.1 Dividing data into multiple parts.

Data is divided into $k+1$ groups, where k denotes the total of interventions. The first section contains pre-intervention period data ($t = 1, 2, \dots, T_1 - 1$), followed by data during the first intervention, i.e. ($t = T_1, T_1 + 1, T_1 + 2, \dots, T_2 - 1$), and so on until the data from the k th intervention to the end of the data analysis, i.e. ($t = T_k, T_k + 1, T_k + 2, \dots, n$).

2.2.2 Modeling the ARIMA pre-intervention.

Data before the intervention, January 2012 until December 2014, were modeled using the Box-Jenkins ARIMA method. Before modeling, the stationarity of the variance and mean should be checked. Box-Cox transformation method is used to test the stationarity of the variance, and the

stationarity of the mean should be checked using the ADF test. The model that has been created will be used to forecast the observed values throughout the next intervention period.

2.2.3 *Modeling the ARIMA first intervention.*

a. *Making residual plot.*

The residuals from the forecasting results are plotted to determine the b, s, and r order with a confidence interval of width ± 2 times the RMSE of the previous model. Order b is the delay time or the first time the intervention has an effect, and although indicated by the residual, that was the first to pass the confidence interval. Meanwhile, s order gives information about the major residual fluctuation or the time required for the intervention's impact on being stable, and r is the pattern of the impacts of an intervention or lags after a period (b + s) where the residuals form a pattern. To determine the best b, s, and r order involve trial and error of the many alternatives identified by the residual plot.

b. *Parameter estimation of ARIMA intervention.*

Estimate and check the significance of the b, s, and r parameters for the first intervention ARIMA model. Calculations can use the conditional least square method by minimizing the conditional sum of squares errors.

c. *Diagnostic checking model.*

The diagnostic test of the model is based on the examine assumption, i.e., normality distribution and white noise of errors. Shapiro-Wilk is used for error normality testing, and Ljung-Box is used for white noise error testing.

d. *Selection of the best models.*

Several possible models are usually formed during the identification of the intervention order. After confirming that all possible models satisfy the assumptions of white noise and normality of error, the best model can be chosen based on the smallest AIC, SBC, and RMSE values.

2.2.4 *The p-th ARIMA intervention modeling, where $p = 2, 3, 4, \dots, k$.*

In the modeling of the 2nd intervention ARIMA model and so on, the steps taken are the same as the first intervention ARIMA modeling stage.

2.2.5 *Measuring the impact of interventions.*

Based on [9], the ARIMA intervention model equation can be written as

$$Y_t = Y_t^* + N_t, \tag{6}$$

where the actual data is denoted as Y_t , N_t is ARIMA pre-intervention model for error, and Y_t^* is the intervention's impact. So that, the estimated impact of the intervention can be determined using the equation below.

$$\widehat{Y}_t^* = \widehat{Y}_t - \widehat{N}_t \tag{7}$$

where \widehat{Y}_t^* is the intervention's impact, \widehat{N}_t is the forecasting value according to ARIMA pre-intervention model and \widehat{Y}_t shows the forecasting value according to ARIMA intervention model. This calculation can be done with the original data, but it must be returned to its original form before the calculation can be done with the transformed data.

3 Result and discussion

3.1. *ARIMA pre-intervention*

Before the pre-intervention ARIMA model can be developed, the data must satisfy the assumptions of stationarity in terms of mean and variance. Based on the results of the Box-Cox plot and the unit root ADF-test, the data was found to be stationary both in variance and mean. As a result, model identification can carry out using the original data's ACF and PACF correlograms.

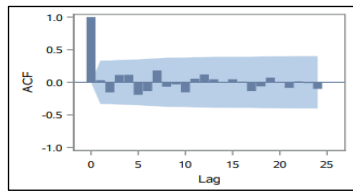


Figure 1. ACF plot of lobster export value.

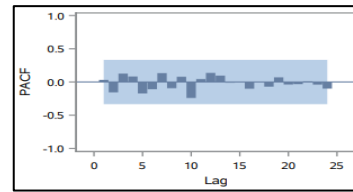


Figure 2. PACF plot of lobster export value.

PACF and ACF graphs of stationary data are shown in figures 1 and 2. The ACF and PACF tend to be cut off after lag 1. Hence, this ARIMA pre-intervention model’s candidate orders, i.e., AR(1), MA(1), or ARMA (1,1). The ARIMA pre-intervention model's possibilities and criteria are listed below.

Table 1. Possible pre-intervention ARIMA models.

Models	Estimate	P-value	AIC	SBC	RMSE	White Noise	Normality
AR(1)	$c = 683169.8$	<.0001	1009.73	1012.89	248019.4	Yes	Yes
	$\phi_1 = 0.5844$	0.0002					
MA(1)	$c = 716529$	<.0001	1010.66	1013.83	248045.1	Yes	Yes
	$\theta_1 = -0.5919$	0.0003					
	$c = 698153.9$	<.0001					
ARMA (1,1)	$\phi_1 = 0.3857$	0.3241	1011.24	1015.55	248052.6	Yes	Yes
	$\theta_1 = -0.2863$	0.1667					

Based on the criteria of the three models in table 1, it was found that the AR(1) model was the best model to explain the export value of lobster (*Panulirus spp.*) in Indonesia before the first intervention. The pre-intervention ARIMA model is possible to write as

$$\hat{Y}_t = \frac{683169.8}{(1 - 0.5844B)} = \hat{N}_t. \tag{8}$$

3.2. ARIMA first intervention model

After obtaining the ARIMA pre-intervention model, forecasting for the data in the first intervention period, January 2015 to December 2016, was performed, and the residual value was obtained to determine the first intervention model. The first intervention in this analysis is implementing Ministerial Regulation No. 1 of 2015 related to the fishing lobster seeds ban policy since January 2015, which follows the step function.

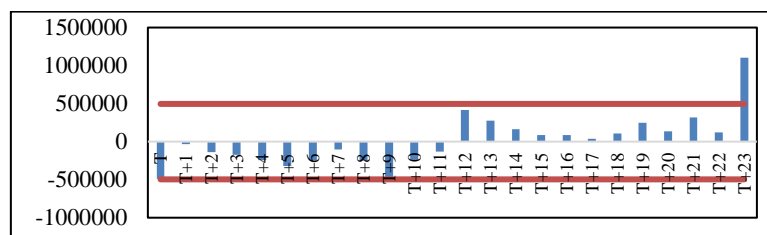


Figure 3. The plot of the residual data for the first intervention period.

The resulting residual plot is shown in Figure 3. It is known that at the time T_1 and $T_1 + 9$ the residual reaches the confidence interval of RMSE. Hence the order of $b = 0$ or $b = 9$ is suspected. Furthermore, the residual at $T_1 + 12$ and $T_1 + 23$ approaches and exceeds the confidence interval of RMSE. A trial and error procedure is used to find the best combination based on these times. Following the estimation procedure and diagnostics checking models, the optimal orders were $b = 9$, $s = (3, 14)$, and $r = 0$. The estimation and diagnostic checking model of the first intervention model are presented below.

Table 2. Parameters estimation and diagnostics checking of the first intervention model.

Parameters		Normality Error		White Noise Error		
Estimate	P-value	Shapiro Wilk	P-value	Lag	Ljung-Box Stats	P-value
$c = 788605.3$	<.0001			6	2.08	0.8373
$\phi_1 = 0.72374$	<.0001			12	16.32	0.1297
$\omega_{0\ 9} = -350577$	0.0449	0.9507	0.1019	18	20.68	0.2411
$\omega_{3\ 9} = -468437.1$	0.0103			24	29.20	0.1739
$\omega_{14\ 9} = -954671.6$	<.0001			30	31.88	0.3251
				36	34.17	0.5079

According to table 2, all intervention parameters are significant at a significance level of 5%. Model diagnostics checking shows that the normally distributed and white noise errors assumptions were met by the first step function intervention of the ARIMA model. Therefore, the ARIMA first intervention model of the lobster (*Panulirus spp.*) export value in Indonesia can be written as

$$\hat{Y}_t^1 = -350577S_{1,t-9} + 468437,1S_{1,t-12} + 954671,6S_{1,t-23} + \frac{(788605,3)}{(1 - 0,72374B)}. \tag{9}$$

3.3. ARIMA second intervention model

After getting the first intervention model, data forecasting was carried out in the second intervention period, January 2017 to April 2020, applying the first intervention model. The second intervention in this analysis is the implementation of Ministerial Regulation No. 56 of 2016, which follows the step function, and is related to the fishing and export lobster seeds ban policy since January 2017. The residual value is then calculated to determine the second intervention model.

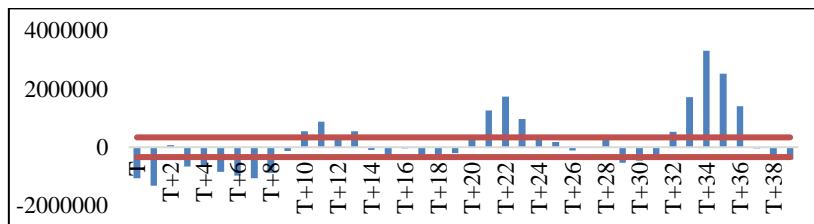


Figure 4. The plot of the residual data period after the second intervention.

Based on the residual value plot in Figure 4, it is known that the residuals cross the confidence interval at time T, T+1, T+3 to T+8, T+10, T+11, T+13, thus the value of order b is presumed to be one of them from that period. However, the value of order r = 0 since the residuals are random or have no pattern. After a lot of trial and error, it was discovered that the order b = 11, s = (10, 22, 23, 25, 26), r = 0 is the optimum one for achieving parameter, white noise, and error normality significance. The following table summarizes the outcomes of parameter estimates and diagnostics checking models.

Table 3. Parameter estimation and diagnostics checking of the ARIMA second intervention model.

Parameters		Normality Errors		White Noise Errors		
Estimate	P-value	Shapiro Wilk	P-value	Lag	Ljung-Box Stats	P-value
$c = 616214.3$	0.0002			6	4.98	0.4187
$\phi_1 = 0.33827$	0.0131			12	9.12	0.6110
$\omega_{0\ 9} = -486050.2$	0.0386	0.9806	0.4216	18	12.62	0.7611
$\omega_{3\ 9} = -587549.4$	0.0151			24	20.65	0.6022
$\omega_{14\ 9} = -611743.9$	0.0021			30	28.65	0.4833
$\omega_{0\ 11} = 622074.9$	0.0245			36	36.84	0.3838
$\omega_{10\ 11} = -903025.6$	0.0013			42	39.35	0.5439
$\omega_{22\ 11} = -2051322.6$	<.0001			48	42.34	0.6657

At a significance level of 5%, all intervention parameters are significant, and diagnostics checking shows that the second step function intervention ARIMA model has met the normality and white noise errors assumptions, according to table 3. The second intervention model can be expressed mathematically as

$$\hat{Y}_t^2 = -473859,7 S_{1,t-9} + 573761,5S_{1,t-12} + 674217,3S_{1,t-23} + 575966,1S_{2,t-11} + 913232,3S_{2,t-21} + 1215630,8S_{2,t-33} + 1411166,9S_{2,t-34} - 1383485,4S_{2,t-36} - 1691037,1S_{2,t-37} + \frac{587267}{(1-0,45579B)} \tag{10}$$

3.4. The impact of the first intervention

According to model (9), the impact of the Ministerial Regulation No.1 of 2015 or the first intervention has been delayed for nine months because it only began in October 2015, caused at the time the policy is strictly enforced [12]. The difference between the estimated value of the first intervention in equation (9) and the estimated value of pre-intervention ARIMA in equation (8) is used to calculate the magnitude of the first intervention's impact. Table 4 presents the magnitude impacts of Ministerial Regulation No.1 of 2015 or the first intervention.

Table 4. The magnitude impacts of the first intervention (USD).

t	Period	ARIMA First Intervention	ARIMA pre-intervention	Magnitude Impacts	Percentage
T ₁ + 9 to T ₁ + 11	October 2015-December 2015	178627.9	682083.6	-503455.7	-73.81%
T ₁ + 12 to T ₁ + 22	January 2016-November 2016	988814.5	682953	305861.5	44.79%
T ₁ + 23	December 2016	1785212	683169.2	1102042.8	161.31%

According to table 4, the initial impact of the first intervention was a reduction in the export value of lobster (*Panulirus spp.*) by 503 thousand USD, down 73.81 percent compared to the same period before the intervention. After that period, impacts did not increase or decrease significantly, so, until December 2009, the impacts decided to become constant. After one year, the regulation was able to increase the export value of lobster (*Panulirus spp.*) by 305 thousand USD or raise 44.79 percent. The impact began to increase in the last period of this intervention, in December 2016, the Indonesian lobster (*Panulirus spp.*) export value increase by 1,1 million USD or increase 161,31 percent. The increase was owing to a 220 percent increase in Indonesian lobster export volume compared to the previous month. Due to the emergence of new markets for Indonesian lobster exports, such as Hong Kong, the United Kingdom, Spain, France, and Iran, the volume of lobster exports has increased significantly.

During the intervention period, there were two distinct impacts: in the first year of the intervention, the value of exports tended to fall, and in the second year, the value of exports tended to grow. These findings are consistent with research [13], which concludes that Australia's strategy of establishing a minimum lobster catch size can cut income in the first year but can improve income the following year. This conclusion is backed up by research [14] and [15], which claim that raising the lobster capture size restriction will boost the catch in the long run due to the accumulation of little lobsters permitted to grow and develop organically in the sea. Furthermore, the intervention's influence was felt until the conclusion of the intervention period, demonstrating that the policy on the restriction of catching lobster seeds, as specified in Permen KP No. 1 of 2015, had a long-term effect [1,16].

3.5. The impact of the second intervention

Based on the model (10), the impact of the Ministerial Regulation No.56 of 2016 or the second intervention has been delayed for 11 months as it only began in December 2017. It spent almost a year since this policy has had a significant impact because the lobster seeds produced from the aquaculture process are still small. It does not have many impacts on the export value of Indonesian lobster. These results are in line with a report from the Wales Ministry of Natural Resources [17]. The difference

between the estimated value of the second intervention in equation (10) and the estimated value of ARIMA first intervention in equation (9) is used to calculate the magnitude of the second intervention's impact. Table 5 presents the magnitude impacts of Ministerial Regulation No.56 of 2016 or the second intervention.

Table 5. Magnitude impacts of the second intervention (USD).

t	Period	ARIMA Second Intervention	ARIMA First Intervention	Magnitude Impacts	Percentage
$T_2 + 11$ to $T_2 + 20$	December 2017 - September 2018	2672149	1859569	812580	43.69%
$T_2 + 21$ to $T_2 + 32$	October 2018 - September 2019	2928896	1861075.1	1067823.9	57.38%
$T_2 + 33$	October 2019	3432021	1861135.7	1570885.3	84.40%
$T_2 + 34$ to $T_2 + 35$	November 2019 - December 2019	4835936	1861136.1	4649799.9	249.81%
$T_2 + 36$	January 2020	3175397	1861137.5	1314259.5	70.62%
$T_2 + 37$ to $T_2 + 39$	February 2020 - April 2020	1607005	1861137.6	-254132.6	-13.65%

Based on table 5, the initial impact of the second intervention in December 2017 significantly increased the export value of lobster (*Panulirus spp.*) by 43.69 percent compared to the export value of lobster in the first intervention period. Since that time left, the impacts decided to become constant until September 2018. Thereafter, the impact increased till the end of 2019. However, the impact of this intervention will be decreased in 2020 because of the Covid-19 pandemic. Due to a considerable increase in lobster prices in numerous Indonesian lobster export markets, including China, Singapore, Malaysia, Taiwan, and Hong Kong, the enhanced impact from October to December 2019 was quite high. A rise in global food costs triggered the price increase. Furthermore, throughout this time, global climate change contributed to a reduction in world lobster production by causing harm to the coral reef environment, which serves as a habitat for lobsters [18]. The policy on the ban of fishing and exporting lobster seeds, as outlined in Ministerial Regulation No. 56 of 2016, has a positive impact, namely raising the lobster export value (*Panulirus spp.*). Even if there is a decline in the growth in impact towards the end of the intervention period, the ensuing impact continues to grow. However, the influence felt until the conclusion of the time was still significant, indicating that the policy's impact is long-lasting [4].

4. Conclusion

Based on the result and discussion, we conclude that both Ministerial Regulation No. 1 of 2015 and Ministerial Regulation No. 56 of 2016 have a significant impact on the export value of lobster (*Panulirus spp.*) in Indonesia. Ministerial Regulation No. 1 of 2015 has a positive effect, increasing the export value of Indonesian lobster (*Panulirus spp.*) even though the initial impact occurred in October 2015, 9 months after the policy's implementation, reduced the export value of Indonesian lobster by 503 thousand USD. Meanwhile, Ministerial Regulation No. 56 of 2016 is increasing the lobster (*Panulirus spp.*) export value in Indonesia. The initial impact occurred 11 months after the implementation. The increasing impact lasted until December 2019, with an even bigger impact. However, there was a reduction in the impact because of the Covid 19 Pandemic in 2020.

Acknowledgment

The authors would like to express our gratitude to Politeknik Statistika STIS for all support in carrying out this research. Besides that, the authors thank the Indonesia Central Bureau of Statistics (BPS), which has provided the data in this research.

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