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Time Series Analysis on Indian Mackerel Retail Price in Peninsular Malaysia

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Abstract: Forecasting fish price has been started for a long time worldwide. The main objective of this study is to predict the monthly retail price of Indian Mackerel in Peninsular Malaysia based on the 9 years data (2007-2015) using two methods which are Box-Jenkins method and Holt's Linear Trend method. Analyse data showed that the Holt's linear trend model and autoregressive integrated moving average or ARIMA (0, 1, 1) $(0, 0, 0)_{12}$ model were proposed. The diagnostic checking for the estimated models confirmed the adequacy of the models. The result of the study showed that the Holt's linear trend method was become the better model with the lower root mean square error (RMSE) and mean absolute percentage error (MAPE). Later, this method has been used to forecast 3 months upcoming Indian Mackerel price eventhough both models have been proven successful in forecasting the monthly fish prices. In conclusion, the potential result from this study could be used in helping fish farmers in their annual planning of increasing income especially in Peninsular Malaysia.

Keywords: Forecasting, Indian Mackerel, Box-Jenkins, Holt's Linear Trend, ARIMA

1. Introduction

One of the most well-known industries that contribute in national economy of Malaysia is the fisheries sector which become important in the national income, foreign exchange and employment in the country [1]. Fish plays an important role as an animal protein consumption supplier in the population. A total of animal protein consumption in Malaysia for Malay ethnics is 175 ± 143 g/day which is higher than Chinese and Indian ethnics with 152 ± 133 g/day and 136 ± 141 g/day respectively [2].

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Forecasting the fish price have a long history of study, for example, Hudson & Capps forecasted the hard blue crabs price using time series method and econometric method [3]. Vukina & Anderson applied the State-Space method to forecast the price of salmon and the result showed that four out of five times series follow random walk and cyclic behaviour was indicated in time series of prices [4]. Park forecasted the Walleye Pollock landings in Korea using seasonal autoregressive integrated moving average (SARIMA) and the result showed the fluctuations of the monthly catches of Walleye Pollock at the 12 months period [5]. Floros & Failler indicated that autoregressive moving average (ARMA) model fitted and forecasted the monthly fisheries prices of 12 species landed which are Anglerfish, Cod, Crabs, Dogfish, Haddock, Hack, Lemonsole, Mackerel, Plaice, Saithe, Sole and Whiting [6].

Paul applied autoregressive integrated moving average (ARIMA) to predict the monthly wholesale price of Rohu and it was showed that the ARIMA was better method to predict the wholesale price due to value of forecast were near to the actual value [7]. Perera et al. used seasonal ARIMA for price prediction of marine fish and it showed that the nominal price have an increasing trend but there is no an increasing trend for real prices [8]. Time series analysis of fish prices has been important tool for fisheries management and decision making as it reveals hidden trends and seasonality patterns. Therefore, the objective of this paper was to predict the monthly retail price of Indian Mackerel in Peninsular Malaysia using Box-Jenkins and Holt's linear trend method. The comparison between these two model using the root mean square error (RMSE) and mean absolute percentage error (MAPE) will highlight better model.

2. Materials and Methods

2.1 Materials

The data for this study were obtained from the Fisheries Department of Malaysia. The data that involved were the monthly retail price of Indian Mackerel for 9 years from 2007-2015 in Peninsular Malaysia. The method that will be used to forecast the monthly retail price of Indian Mackerel were Box-Jenkins ARIMA method and Holt's Linear Trend method. In this paper, we will predict the Indian Mackerel price using the two method. The criterion that will be used as forecast accuracy to measure the performance between the ARIMA and Holt's linear trend method was the root mean square error (RMSE) and mean absolute percentage error (MAPE).

2.2 Methods

2.2.1 Autoregressive Integrated Moving Average (ARIMA)

The ARIMA method is often applied to a univariate time series data. This method is based on Box-Jenkins methodology. Basically, there are four general stages in Box-Jenkins methodology, namely identification, estimation, diagnostic checking and forecasting [9]. The method identification stages starts to check if the data are stationary. The next step is an estimation of selection ARIMA models parameter. The third step is a model checking to ensure the model is adequate and the last step is to forecast the future outcomes based on the past data [9].

At first, a time series data should be in a stationary condition before it can be analyzed using Box-Jenkins methodology. A time series is said to be stationary if its mean and variance remains unchanged over time [10]. Test that can be used to examine the stationary of variance is Box-Cox transformation. The Box-Cox is indexed by $\lambda = 1$, for transforming the data to a normal shape [11].

Besides Box-Cox, autocorrelation function (ACF) and partial autocorrelation function (PACF) plots also can be used to check the stationary. Differencing can make the series of the data to be a stationary data. Box & Jenkins proposed an ARIMA (p, d, q) models where p stands for the order of the autoregressive process, AR (p) [9]. d stands for the order of the data stationary and q stands for the order of the moving average, MA (q). The equation of ARIMA(p, d, q) can be written as described in Eq. 1 - Eq. 3 [9],

$$\phi_p(B)(1-B)^d Y_t = \theta_q(B)\varepsilon_t \qquad Eq. 1$$

with

$$\phi_p(B) = 1 - \phi_1 B - \phi_2 B^2 - \cdots - \phi_p B^p \qquad Eq. 2$$

$$\theta_q(B) = 1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q \qquad Eq. 3$$

where Y_t is appropriately transformed in period t, B is the backshift operator has the effect of shifting time period t to time period $t-1$, thus, $BY_t = Y_{t-1}$ and $B^2Y_t = Y_{t-2}$, d is the number of regular difference and ε is the random process.

The Ljung-Box test can be used to check whether the model is adequate or not. The equation of the Ljung-Box test is shown in Eq. 4 as described by Hyndman & Anthanasopoulos [12].

$$Q = n(n+2)\sum_{k=1}^{m} \frac{\widehat{r_k}}{n-k} \qquad Eq. 4$$

where r_k is the estimated autocorrelation of the series at lag k, n is the number of residuals, m is the number of lags being tested. If the p-value associated with the Q statistics are more than α= 0.05 (p-value > α), it can be concluded that the model is adequate.

2.2.2 Holt's Linear Trend

Holt's linear trend method is a time series analysis that allow the data with a trend to forecast. The forecast is computed as the total of the estimated level of the time series at the current time l_T plus the estimated slope b_T of the series at the current point. The forecast equation is described by Hyndman & Athanasopoulos [12] as in Eq. 5,

$$\hat{y}_{T+P}(T) = l_T + pb_T \qquad Eq. 5$$

where l_T is the estimate of the level in time period T, b_T is the estimate of the trend in time period T, $\hat{y}_{T+P}(T)$ is the linear forecast from T onwards, p is the future number of years that would like to predict.

2.3 Measurement Error

2.3.1 Root Mean Square Error (RMSE)

The root mean square error (RMSE) is the square root of the mean of the square of all error. The formula of RMSE can be written as described in Eq. 6 [1].

$$RMSE = \sqrt{\frac{1}{n}\sum_{t=1}^{n}(y_t - \hat{y}_t)^2} \qquad Eq. 6$$

where y_t is the actual value of period t, $\widehat{y_t}$ is the forecasted value of period t, n is the total number of n periods.

2.3.2 Mean Absolute Percentage Error (MAPE)

The mean absolute percentage error (MAPE) is a measure of prediction accuracy of a forecasting method. The formula of MAPE can be written as described in Eq. 7 [1].

$$MAPE = \frac{100}{n}\sum_{t=1}^{n}\left|\frac{y_t - \widehat{y_t}}{y_t}\right| \qquad Eq. 7$$

where y_t is the actual value of period t, $\hat{y}_t$ is the forecasted value of period t, n is the total number of n periods.

3. Results and Discussion

3.1 Box-Jenkins

The time series plot of the Indian Mackerel price shows that there is a cyclic pattern and it was obvious that there was no seasonality present in the data (Figure 1). In detecting stationary of the data for time series approach, ACF plot have been used. The ACF plot showed that the plot was decays exponentially, which confirm that the series was non-stationary (Figure 2).

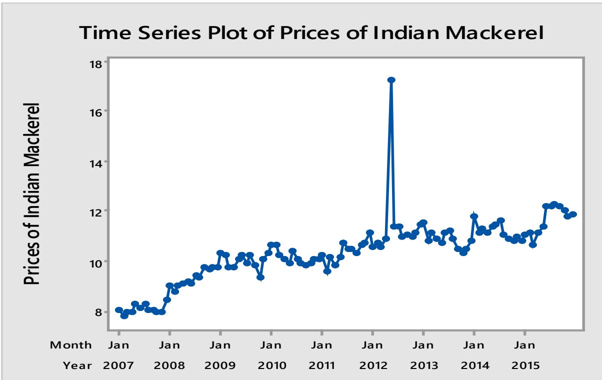

Figure 1: Time series plot of Indian Mackerel price

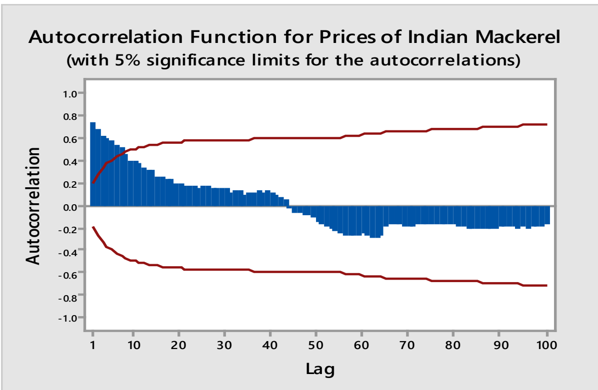

Figure 2: ACF plot of Indian Mackerel price

Since the data were not stationary, the differencing was needed in this analysis. The first differencing was required. Figure 3 and Figure 4 showed the ACF and PACF plot of Indian Mackerel retail price for the 1^{st} differencing order. From this graph, it showed that the data were stationary and the second differencing was not needed.

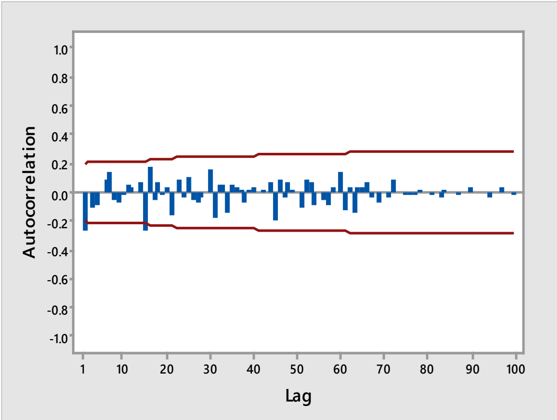

Figure 3 : ACF plot of Indian Mackerel for the 1st differencing

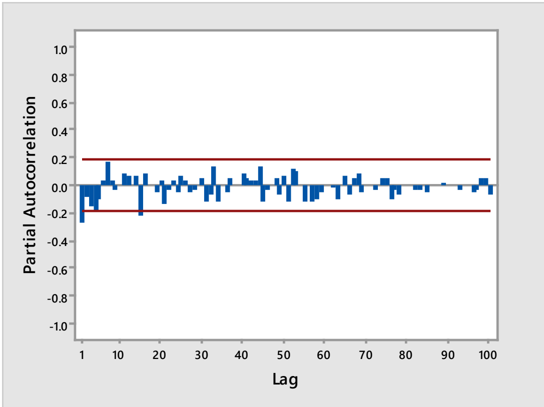

Figure 4: PACF plot of Indian Mackerel for the 1st differencing

The best fitted models for Indian Mackerel was shown in Table 1. The value that used to determine the best model were MSE, *p*-value and *p*-value for the Ljung-Box. Ljung-Box test is a test to check the residual autocorrelation. The result showed that ARIMA (0, 1, 1) (0, 0, 0)$_{12}$ is an adequate model since it has the lowest MSE, *p-value* < 0.05 and the *p-value* (Ljung-Box) > 0.05.

Table 1: Model's parameter and Ljung-Box comparison

Model	MSE	*P*-Value	*P*-Value (Ljung-Box)			
ARIMA (1, 1, 1)	13284	0.199 0.001	0.493	0.372	0.446	0.572
ARIMA (1, 1, 0) (0, 0, 0)$_{12}$	13606	0.003	0.136	0.109	0.128	0.221
ARIMA (1, 1, 0) (0, 0, 1)$_{12}$	13601	0.003 0.360	0.176	0.170	0.178	0.304
ARIMA (0, 1, 1) (0, 0, 0)$_{12}$	13351	0.000	0.203	0.182	0.263	0.388
ARIMA (0, 1, 1) (0, 0, 1)$_{12}$	13295	0.000 0.295	0.279	0.290	0.375	0.530

3.2 Holt's Linear Trend

Table 2 showed the alpha *(α)* and gamma *(γ)* value for Holt's linear trend method which was optimised using solver in Microsoft Excel. Figure 7 showed that the value of fitted value was significant with actual value of Indian Mackerel price for Holt's linear trend method.

Table 2: Optimized alpha (α) and gamma (γ) value

Parameters:	Alpha, α	0.894
	Gamma, γ	0.017

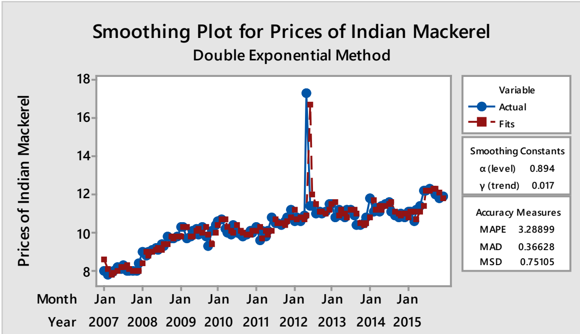

Figure 5: Actual versus predicted plot

3.3 Comparison of Time Series Method

Using two type of the time series method which were ARIMA (0, 1, 1) $(0, 0, 0)_{12}$ and Holt's linear trend method, the performance of each model was measured by their RMSE and MAPE values. Model that have lower RMSE and MAPE value will tend to be the better forecasting method for this research. From the Table 3, the better method for this research was Holt's linear trend method since it had the smaller value of RMSE and MAPE.

Table 3: RMSE and MAPE value of ARIMA and Holt's Linear Method

Time Series Method	RMSE	MAPE
ARIMA (0, 1, 1) $(0, 0, 0)_{12}$	0.8982	3.39%
Holt's Linear Method	0.8666	3.29%

4. Conclusion

In this study, the Holt's linear trend method was the suitable method to forecast the monthly retail price of Indian Mackerel for the period of 2007-2015 since it had lower RMSE and MAPE values. The Holt's linear trend method was used to forecast a three months upcoming Indian Mackerel price. Since the Indian Mackerel is one of the important fish, the price indicator of the Indian Mackerel become important. The information provided by the monthly retail price of Indian Mackerel was enough to help the fish farmers and the planners for future planning in Peninsular Malaysia. Time series analysis of fish prices has been important tool for fisheries management and decision making as it reveals hidden trend and seasonality patterns.

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