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Case Study

Forecasting Rice Prices with Holt-Winter Exponential Smoothing Model

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A B S T R A C T

Rice, as a staple food, plays a crucial role in global food security. Accurate forecasting of rice prices is essential for policymakers, farmers, and consumers alike. This article explores the application of the Holt-Winter exponential smoothing model to predict rice prices. Holt-Winter method is chosen for its ability to capture both trend and seasonality in time series data, which are prominent features in agricultural commodity prices such as rice. The study analyzes historical price data, identifies trends, seasonality, and incorporates smoothing parameters in additive and multiplicative methods. Results indicate that additive method of Holt-Winter exponential smoothing provides a better performance. This research contributes valuable insights to the field of agricultural economics and informs strategies for managing food supply chains and market stability.

INTRODUCTION

Experts say that this price increase is the result of the government's strategy to maintain rice prices in the market. As of January 18, 2023, the average price of rice reached IDR 12,800 per kilo, according to data from the Strategic Food Price Information Center (PIHPS). In addition to that, the price of Super I quality rice reaches IDR 14,150 per kilogram. Grade I and secondary rice costs IDR 11,650 per kilogram. According to the Bureau of Statistics (BPS), rice prices will reach IDR 11,877 per kilo in November 2022. Perum Bulog has agreed to distribute 100,000 tonnes of rice through market operations from January 17, 2022 to control rising prices [1].

Since rice is the staple food of Indonesian people, price trends will have a significant impact on Indonesia's inflation rate. The inflation weight of rice is 3.32 percent, the highest among all food groups. Rice prices continue to soar due to the abnormal weather caused by the El Niño phenomenon. Apart from increasing demand, the supply of rice from producing areas also continues to decline [2].

Rising rice prices can place an economic burden on households with limited income, limiting their ability to meet their basic food needs [3]. Additionally, forecasting rice prices will allow governments to design pricing and subsidy policies more effectively, focusing on protecting community groups that are more susceptible to food price fluctuations [4].

There are various forecasting methods that have been developed to deal with complexity and variation in data, with the objective of providing accurate estimates of future events. Along with the development of technology and data analysis, many forecasting methods have been introduced, varying from classical methods such as moving average forecasting to more sophisticated methods such as linear regression and temporal modeling techniques such as ARIMA (AutoRegressive

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Integrated Moving Average) and Holt-Winters Exponential Smoothing. An in-depth understanding of these methods is essential in choosing an approach that suits the characteristics of the data and specific analysis needs.
The Holt-Winters Exponential Smoothing method is used for forecasting food prices in Pamekasan Regency with good enough accuracy [5]. Weighted moving average method is used to forecast monthly price of rice at the miller level with the best weight combination of 10,2,1 [6]. Fuzzy Time Series Markov Chain on data testing the period November 2020-July 2022 obtained a very good MAPE value of 0.81% in forecasting monthly price of rice at the miller level [7]. In [8], the best forecasting was performed for the Average Rice Price at the Indonesian Wholesale Trade Level from July 2020 to June 2021 with SARIMA (Seasonal Autoregressive Integrated Moving Average) method. From the research, ARIMA (1, 1, 0) (0, 0, 3)^{12} is obtained as best model.

In this study, we attempted to use Holt-Winters Exponential Smoothing method for forecasting rice price at the wholesale trade level. Holt (1957) and Winters (1960) extended Holt's method to capture seasonality. The Holt-Winters seasonal method comprises the forecast equation and three smoothing equations — one for the level l_t, one for the trend b_t, and one for the seasonal component s_t, with corresponding smoothing parameters α, β^* and γ. There are two variations to this method that differ in the nature of the seasonal component. The additive method is preferred when the seasonal variations are roughly constant through the series, while the multiplicative method is preferred when the seasonal variations are changing proportional to the level of the series. With the additive method, the seasonal component is expressed in absolute terms in the scale of the observed series, and in the level equation the series is seasonally adjusted by subtracting the seasonal component. Within each year, the seasonal component will add up to approximately zero. With the multiplicative method, the seasonal component is expressed in relative terms (percentages), and the series is seasonally adjusted by dividing through by the seasonal component [9].

METHOD

Data Collection

Data used in this study is the average price of rice at the wholesale level in Indonesia from 2014 to 2023 [10].

Holt's Winter Exponential Smoothing

The Holt-Winters (HW) method is an extension of the Holt method, and is applied whenever the data behaviour is trendy and is seasonal. Relatively to the seasonal type, it can be additive or multiplicative, depending on the oscillatory movement along the time period. In both versions, forecasts will depend on the following three components of a seasonal time series: its level, its trend and its seasonal coefficient. The additive version ought to be considered whenever the seasonal pattern of a series has a constant amplitude over time. In the additive case, the series can be written by

$$Y_t = T_t + S_t + e_t \tag{1}$$

where T_t represents the trend (the sum of the level and slope of the series at time t), S_t is the seasonal component, and e_t are error terms with mean zero and constant variance. The recursive equations of the additive HW methods, for level, trend, seasonal factors and forecast, with $h_s^+ = \left[(h-1) \bmod s\right] + 1$ is presented below

Level: $l_t = \alpha\left(Y_t - s_{t-s}\right) + (1-\alpha)\left(l_{t-1} + b_{t-1}\right), 0 \le \alpha \le 1$ (2)

Trend: $b_t = \beta\left(l_t - l_{t-1}\right) + (1-\beta) b_{t-1}, 0 \le \beta \le 1$ (3)

Seasonal: $s_t = \gamma\left(Y_t - l_t\right) + (1-\gamma) s_{t-s}, 0 \le \gamma \le 1$ (4)

Forecast: $\hat{Y}_{t+h} = l_t + h b_t + s_{t-s+h_s^+}, h = 1, 2, \ldots$ (5)

In the multiplicative case, the series can be represented by

$$Y_t = T_t \text{ x } S_t + e_t \tag{6}$$

The recursive equations of the multiplicative HW methods, for level, trend, seasonal factors and forecast, with $h_s^+ = \left[(h-1) \bmod s \right] + 1$ is presented below

Level: $l_t = \alpha \left(\frac{Y_t}{s_{t-s}} \right) + (1-\alpha)(l_{t-1} + b_{t-1}), 0 \le \alpha \le 1$ (7)

Trend: $b_t = \beta (l_t - l_{t-1}) + (1-\beta) b_{t-1}, 0 \le \beta \le 1$ (8)

Seasonal: $s_t = \gamma \left(\frac{Y_t}{l_t} \right) + (1-\gamma) s_{t-s}, 0 \le \gamma \le 1$ (9)

Forecast: $\hat{Y}_{t+h} = l_t + h b_t + s_{t-s+h_s^+}, h = 1, 2, \ldots$ (10)

Where Y_t is the observed data at time *t*, *s* is the length of seasonality (number of months in a season), *h* is the number of forecast ahead, and $\theta = (\alpha, \beta, \gamma)^T$ is the vector of smoothing parameters [11].

Evaluation of Models

There are many kinds of measure which can be used to evaluate the performance of time series models. In this paper, we will use mean absolute error (MAE), mean squared error (MSE), and mean absolute percentage error (MAPE) to compare the three time series models. The formula of MAE, MSE, and MAPE are defined as follows [12] .

$$MAE = \frac{1}{n} \sum_{t=1}^{n} \left| Y_t - \hat{Y}_t \right| \quad (11)$$

$$MSE = \frac{1}{n} \sum_{t=1}^{n} \left(Y_t - \hat{Y}_t \right)^2 \quad (12)$$

$$MAPE = \frac{1}{n} \sum_{t=1}^{n} \left| \frac{Y_t - \hat{Y}_t}{Y_t} \right| \text{ x } 100\% \quad (13)$$

RESULTS AND DISCUSSION

The data in this research is presented in the following graph

Figure 1. Average Price of Rice at the Wholesale Level in Indonesia from 2014 to 2023

From the graph, it can be seen that the data has a trend and seasonal pattern. There is a very significant change in data seen in December 2020 to January 2021. The price of rice has decreased very significantly. We know that this period of time is the Covid 19 pandemic.

Based on the data shown in Figure 1, we analyse this data using Holt-Winter exponential smoothing methods that will compare the additive and multiplicative. The predicted results of additive method with optimal parameters $\alpha = 1$, $\beta = 0.11$, dan $\gamma = 0$ from Eviews 10 are reported in figure below.

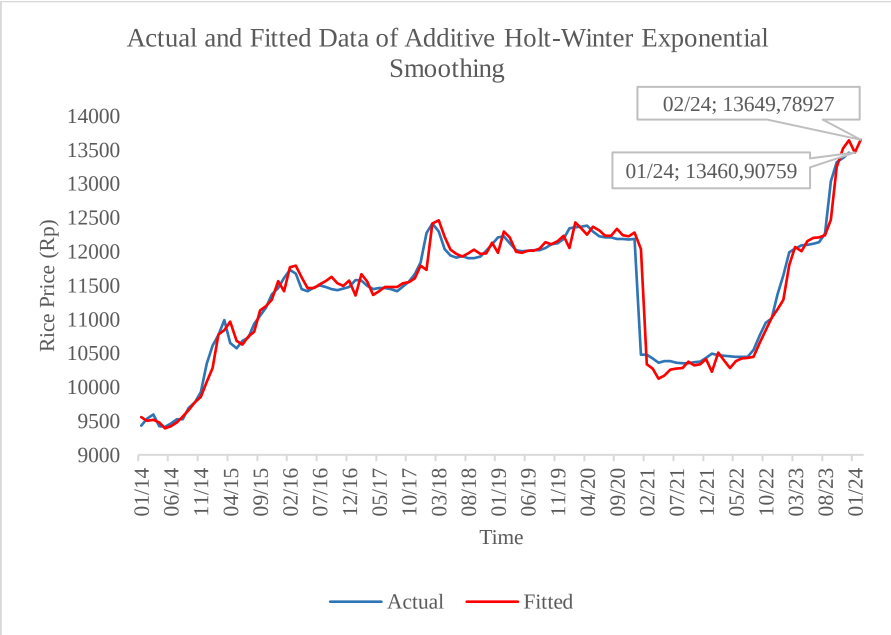

Figure 2. Actual and Fitted Data of Additive Holt-Winter Exponential Smoothing

From Figure 2 we can see the comparison of actual data with simulated data from the additive method. With this method, forecasting is also carried out for the next 2 periods. The result of rice price forecasting for January 2024 is IDR 13,460,907 and for February 2024 is IDR 13,649,789. Meanwhile, the predicted results of multiplicative method with optimal parameters $\alpha = 1$, $\beta = 0.11$, and $\gamma = 0$ from Eviews 10 are reported in figure below.

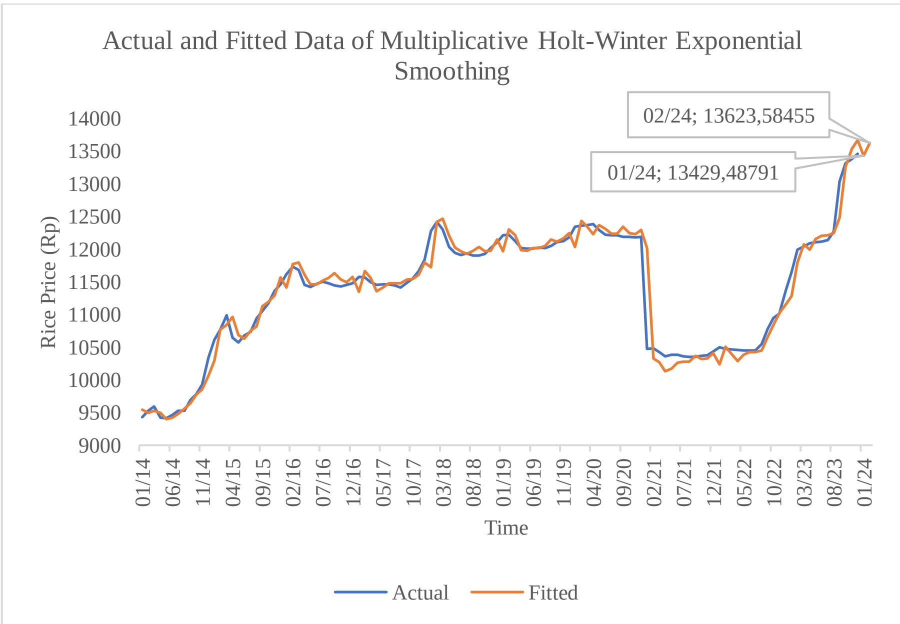

Figure 3. Actual and Fitted Data of Multiplicative Holt-Winter Exponential Smoothing

From Figure 3 we can see the comparison of actual data with simulated data from the multiplicative method. With this method, forecasting is also carried out for the next 2 periods. The result of rice price forecasting for January 2024 is Rp 13,429,487 and for February 2024 is Rp 13,623,789.

To compare the performance of two methods accurately, Table 1 provides the value of the MAE, MSE, and MAPE of each method.

Tabel 1. Performance of Each Method for Predicting Rice Price in Indonesia

Metods of HW Exponential Smoothing	**Evaluation**		
	MAE	**MSE**	**MAPE**
Additive	107.621	38523.475	0.954 %
Multiplicative	108.825	38613.893	0.964 %

According to the results of the model performance shown in Table 1, additive method of HW exponential smoothing gives a fewer value of MAE, MSE, and MAPE than the multiplicative one. Thus, we can say that the additive method is more appropriately used than another one.

CONCLUSION

Holt-Winter exponential smoothing can be performed in 2 ways, additive and multiplicative. In forecasting rice prices, it was found that Holt-Winter exponential smoothing using additive method gave better result. In forecasting rice prices, it is found that Hw with the additive method gives better results. This is indicated by MAE, MSE and MAPE values of the additive method which are lower than multiplicative. In forecasting 2 periods ahead, the average price of rice in January and February 2024 is Rp 13,460,907 and Rp 13,649,789, respectively.

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