

## COMPARISON OF SEVERAL DOUBLE EXPONENTIAL SMOOTHING METHODS ON FORECASTING RICE PRICE IN AMBON CITY

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| ARTICLE INFO                                                                                                                                                                                                                                                                                                                                                                                                             | ABSTRACT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
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| <p><b>Article History</b></p> <p>Received : February 8<sup>th</sup>, 2026<br/>Reviewed : March 5<sup>th</sup>, 2026<br/>Accepted : March 13<sup>th</sup>, 2026<br/>Published : March 17<sup>th</sup>, 2026</p> <p><b>Keywords</b></p> <p>Damped Trend;<br/>Double Exponential Smoothing;<br/>Forecasting;<br/>Rice.</p>                                                                                                  | <p>Rice is one of the staple foods consumed daily by Indonesians. Maluku Province's rice production ranks 28<sup>th</sup> out of 38 provinces in Indonesia in 2024. However, as the provincial capital, Ambon City has no rice production, resulting in a significant price difference between rice and other regions. This study aims to compare the accuracy of the Double Exponential Smoothing Brown Method, Double Exponential Smoothing Holt, and Damped Trend, and to obtain rice price forecasting results for Ambon City using the best model. The methods used are Brown's Double Exponential Smoothing, Holt's Double Exponential Smoothing, and the Damped Trend method. The results of this study indicate that the Damped Trend method with parameters <math>\alpha = 0.9</math>, <math>\beta = 0.9</math>, and <math>\phi = 0.4</math> is the best model with a MAPE value of 0.759%. The forecast results for the period September to December 2025 are respectively IDR 17,796/kg, IDR 17,839/kg, IDR 17,857/kg, and IDR 17,864/kg. This shows that the price of rice in Ambon City during September to December 2025 will increase only slightly.</p> |
| <div>  <p>This article is an open-access article distributed under the terms and conditions of the <a href="https://creativecommons.org/licenses/by-sa/4.0/">Creative Commons Attribution-ShareAlike 4.0 International License</a>. Editor of Beta-Barekeng: J. Math. &amp; Comp. Sci., Published by Beta Math Archipelago</p> </div> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

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## 1. Introduction

In Indonesia, several staple commodities include shallots, garlic, corn, cooking oil, and rice. Among these, rice stands out as one of the primary staples consumed daily by the Indonesian population, with nearly the entire society adhering to a three-meal-a-day dietary pattern [1]. Rice production in Maluku Province ranked 28th out of 38 provinces in Indonesia in 2024, with a total output of 51,031.04 tons. Buru Regency was among the top producing districts/municipalities, yielding 24,609.00 tons, followed by Central Maluku Regency with 20,009.21 tons. However, Ambon City, as the provincial capital, recorded no rice production at all [2]. This situation compels the Ambon City Government to source rice supplies from other districts/municipalities within Maluku or from outside the province to meet local demand. The limited stock due to the absence of local production in Ambon City, combined with its dense population, frequently results in substantially higher prices compared to other regions.

Furthermore, rice price fluctuations are heavily influenced by seasonal harvest patterns: prices tend to decline during harvest seasons and rise during off seasons. These price variations prompt the government to implement policies aimed at stabilizing prices, thereby minimizing losses for both farmers and consumers [3]. Price forecasting is thus essential to anticipate future rice prices, enabling the government to enact proactive measures and policies that mitigate excessive fluctuations.

One effective method for predicting future rice prices is Exponential Smoothing. This approach is widely adopted for forecasting due to its procedural simplicity and ability to accommodate data exhibiting trends and seasonality that may evolve over time. [4]. Double Exponential Smoothing is employed when data patterns exhibit a trend but do not directly address seasonality. This method comprises two variants: Brown's single-parameter Double Exponential Smoothing and Holt's two-parameter Double Exponential Smoothing. Additionally, Holt's variant incorporates an extra parameter to dampen trend movements, known as the Damped Trend method [5]. Based on all those problems and evidence, this study mainly discussed about comparison between Brown's Double Exponential Smoothing, Holt's Double Exponential Smoothing, and the Damped Trend method for forecasting rice price in Ambon City.

## 2. Research Methods

### 2.1. Data Source

The data utilized in this study consist of secondary data on rice prices in Ambon City from July 2020 to August 2025, sourced from the National Strategic Food Price Information Center (PIHPS) website. So that there were 62 data samples obtained in this study.

### 2.2. Brown's Double Exponential Smoothing

The Brown's Double Exponential Smoothing is a linear model introduced by Brown, commonly applied to data exhibiting trend patterns without accounting for seasonality [6]. This method resembles Double Moving Average, as both single and double smoothing values lag the actual data when a trend component is present. Its primary advantage lies in modeling trends effectively with limited data. However, a key drawback is the need for optimal parameter values, which requires considerable time to identify [7].

The parameter used in this method is a single value parameter ( $\alpha$ ), which ranges between 0 and 1. Forecasting with Brown's Double Exponential Smoothing involves the following steps.

- 1) Calculate first smoothing value ( $S'_t$ )

$$S'_t = \alpha Y_t + (1 - \alpha)S'_{t-1} \quad (1)$$

- 2) Calculate second smoothing value ( $S''_t$ )

$$S''_t = \alpha S'_t + (1 - \alpha)S''_{t-1} \quad (2)$$

- 3) Calculate the constant ( $a_t$ )

$$a_t = 2S'_t - S''_t \quad (3)$$

- 4) Calculate slope or trend smoothing value ( $b_t$ )

$$b_t = \frac{\alpha}{1 - \alpha} (S'_t - S''_t) \quad (4)$$

- 5) Calculate forecast value for next period ( $F_{t+m}$ )

$$F_{t+m} = a_t + b_t(m) \quad (5)$$

with,

- $S'_t$  : First smoothing value on t-th period
- $Y_t$  : Actual value on t-th period
- $\alpha$  : Smoothing parameter (  $0 < \alpha < 1$  )

- $S'_{t-1}$  : First smoothing value on previous period
- $S''_t$  : Second smoothing value on t-th period
- $S''_{t-1}$  : Second smoothing value on previous period
- $a_t$  : Constant value on t-th period
- $b_t$  : Slope or Trend smoothing value on t-th period
- $F_{t+m}$  : Forecast value for next period
- $m$  : Number of periods to forecast

As for initialization value to perform this method, it is assumed that  $S'_1 = Y_1$ .

### 2.3. Holt's Double Exponential Smoothing

The Holt's Double Exponential Smoothing operates on the same principle as Brown's but avoids direct application of the Double Exponential Smoothing formula. Instead, this method smooths the trend component using a separate parameter distinct from that applied to the original series [8].

Forecasts from Holt's method are derived using two smoothing parameters ( $\alpha$  and  $\beta$ ), each ranging from 0 to 1. Forecasting with Holt's Double Exponential Smoothing proceeds through the following steps.

- 1) Calculate first smoothing value ( $S'_t$ )

$$S'_t = \alpha Y_t + (1 - \alpha)(S'_{t-1} + b_{t-1}) \quad (6)$$

- 2) Calculate slope or trend smoothing value ( $b_t$ )

$$b_t = \beta(S'_t - S'_{t-1}) + (1 - \beta)b_{t-1} \quad (7)$$

- 3) Calculate forecast value for next period ( $F_{t+m}$ )

$$F_{t+m} = S'_t + b_t(m) \quad (8)$$

with,

- $S'_t$  : First smoothing value on t-th period
- $S'_{t-1}$  : First smoothing value on previous period
- $\alpha$  : Smoothing parameter ( $0 \leq \alpha \leq 1$ )
- $Y_t$  : Actual value on t-th period
- $b_t$  : Slope or Trend smoothing value on t-th period
- $\beta$  : Weighted parameter for trend component ( $0 \leq \beta \leq 1$ )
- $b_{t-1}$  : Slope or Trend smoothing value on previous period
- $F_{t+m}$  : Forecast value for next period
- $m$  : Number of periods to forecast

As for initialization value to perform this method, it is assumed that  $S'_1 = Y_1$  and  $b_1 = Y_2 - Y_1$ .

### 2.4. Damped Trend Method

The Damped Trend method represents an extension of Holt's Double Exponential Smoothing, designed to address data with trend patterns. According to Gardner and McKenzie, incorporating a damping factor into Holt's method dampens the trend, preventing exponential increases or decreases.

Forecasts from Holt's method are derived using three smoothing parameters ( $\alpha$ ,  $\beta$ , and  $\varphi$ ), each ranging from 0 to 1. This method is implemented using the following steps [5].

- 1) Calculate first smoothing value ( $S'_t$ )

$$S'_t = \alpha Y_t + (1 - \alpha)(S'_{t-1} + \varphi b_{t-1}) \quad (9)$$

- 2) Calculate slope or trend smoothing value ( $b_t$ )

$$b_t = \beta(S'_t - S'_{t-1}) + (1 - \beta)\varphi b_{t-1} \quad (10)$$

- 3) Calculate forecast value for next period ( $F_{t+m}$ )

$$F_{t+m} = S'_t + (\varphi + \varphi^2 + \dots + \varphi^m)b_t \quad (11)$$

with,

- $S'_t$  : First smoothing value on t-th period
- $S'_{t-1}$  : First smoothing value on previous period
- $\alpha$  : Smoothing parameter ( $0 \leq \alpha \leq 1$ )
- $Y_t$  : Actual value on t-th period
- $b_t$  : Slope or Trend smoothing value on t-th period
- $\beta$  : Weighted parameter for trend component ( $0 \leq \beta \leq 1$ )
- $\varphi$  : Damped smoothing parameter ( $0 \leq \varphi \leq 1$ )

- $b_{t-1}$  : Slope or Trend smoothing value on previous period  
 $F_{t+m}$  : Forecast value for next period  
 $m$  : Number of periods to forecast

As for initialization value to perform this method, it is assumed that  $S'_1 = Y_1$  and  $b_1 = Y_2 - Y_1$ .

## 2.5. Mean Absolute Percentage Error

In forecasting contexts, accuracy serves as the primary criterion for rejecting or selecting a forecasting method, assessed through forecast error metrics. This study employs Mean Absolute Percentage Error (MAPE) to identify the best model and evaluate forecast accuracy [9].

MAPE measures the average absolute error as a percentage of the actual values, providing a relative gauge of forecasting precision, that is calculated using the following formula [10].

$$MAPE = \left( \frac{100}{n} \right) \sum_{t=1}^n \frac{|Y_t - F_{t+m}|}{Y_t} \quad (12)$$

with,

- $Y_t$  : Actual value on t-th period  
 $F_{t+m}$  : Forecast value on respective t-th period  
 $n$  : Number of periods

## 2.6. Research Procedure

This study conducted several procedures as follows:

- 1) Constructed and analyzed the pattern of rice prices in Ambon City during the study period to identify data characteristics.
- 2) Developed prediction model for rice price in Ambon City using Brown's Double Exponential Smoothing method based on Eq. (1) to (5). Several numbers of parameter  $\alpha = \{0.0; 0.1; 0.2; 0.3; 0.4; 0.5; 0.6; 0.7; 0.8; 0.9; 1.0\}$  are simulated to get a prediction model.
- 3) Developed prediction model for rice price in Ambon City using Holt's Double Exponential Smoothing method based on Eq. (6) to (8). Several combinations of parameters  $(\alpha, \beta) = \{0.0; 0.1; 0.2; 0.3; 0.4; 0.5; 0.6; 0.7; 0.8; 0.9; 1.0\}$  are simulated to get a prediction model.
- 4) Developed prediction model for rice price in Ambon City using Damped Trend method based on Eq. (9) to (11). Several combinations of parameters  $(\alpha, \beta, \varphi) = \{0.0; 0.1; 0.2; 0.3; 0.4; 0.5; 0.6; 0.7; 0.8; 0.9; 1.0\}$  are simulated to get a prediction model.
- 5) Calculated prediction accuracy of each method using Mean Absolute Percentage Error (MAPE) based on Eq. (12). This calculation also applied for all combinations of parameters in each method.
- 6) Compared prediction of rice price in Ambon City across those smoothing method based on least MAPE value. This comparison also decides best combination of parameters used in each method.
- 7) Generate rice price forecasts for Ambon City from September to December 2025 using the best-performing model.

To conducted some procedures as mentioned above, we used software R to help develop these models and calculate MAPE values.

## 3. Results And Discussion

### 3.1. Descriptive Statistics and Trend Analysis

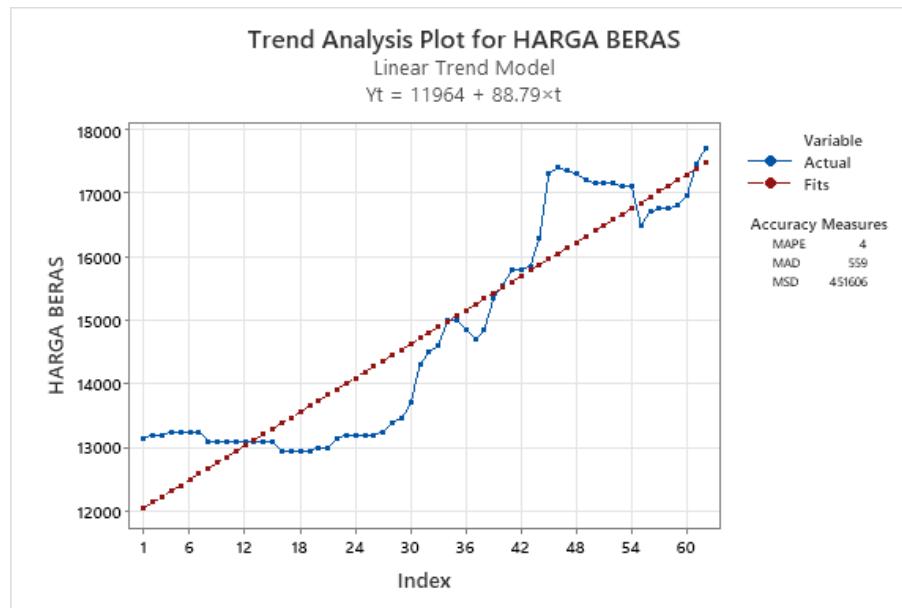
Descriptive statistics are employed to summarize data characteristics. The descriptive statistics for rice prices in Ambon City are presented in Table 1.

Table 1. Descriptive statistics

| Statistic          | Value (IDR/kg) |
|--------------------|----------------|
| Minimum            | 12,950         |
| Mean               | 14,760         |
| Standard Deviation | 1,739          |
| Maximum            | 17,700         |

Based on Table 1, over the period from July 2020 to August 2025 the lowest rice price in Ambon City was IDR 12,950/kg, recorded from October 2021 to January 2022, while the highest price was IDR 17,700/kg in August 2025.

The average rice price during this period was IDR 14,760/kg, with a standard deviation of IDR 1,739/kg, indicating relatively low-price variability. To determine whether rice prices exhibited an upward or downward trend, a trend test is conducted, with results displayed in **Figure 1**.



**Figure 1.** Trend analysis plot (Application Source: R Software)

Based on **Figure 1**, it is revealed that rice prices in Ambon City from July 2020 to August 2025 exhibited a trend component. This is evidenced by the fitted line representing the trend, which displays a consistent linear upward trajectory across months. Consequently, Brown's Double Exponential Smoothing, Holt's Double Exponential Smoothing, and Damped Trend method were appropriate for forecasting rice prices in Ambon City for 2025.

### 3.2. Prediction Model with Brown's Double Exponential Smoothing

The Brown's Double Exponential Smoothing involved two smoothing iterations followed by forecasting. Prior to this, the value of smoothing parameter ( $\alpha$ ) must be determined to smooth the actual periodic time series data. Based on simulations, it acknowledged that value  $\alpha = 0.7$  have the best prediction model based on MAPE values among others.

So that in this study, we performed experimental calculations using Brown's Double Exponential Smoothing method with  $\alpha = 0.7$  for predict rice prices in Ambon City. The result is presented in **Table 2**.

**Table 2.** Calculation of forecast with Brown's Double Exponential Smoothing

| $t$ | $Y_t$ | $S'_t$   | $S''_t$  | $a_t$    | $b_t$   | $F_{t+m}$ |
|-----|-------|----------|----------|----------|---------|-----------|
| 1   | 13150 | 13150.00 | 13150.00 | 13150.00 | 0.00    |           |
| 2   | 13200 | 13185.00 | 13174.50 | 13195.50 | 24.50   | 13150.00  |
| 3   | 13200 | 13195.50 | 13189.20 | 13201.80 | 14.70   | 13220.00  |
| 4   | 13250 | 13233.65 | 13220.32 | 13246.99 | 31.12   | 13216.50  |
| 5   | 13250 | 13245.10 | 13237.66 | 13252.53 | 17.35   | 13278.10  |
| 6   | 13250 | 13248.53 | 13245.27 | 13251.79 | 7.61    | 13269.88  |
| 7   | 13250 | 13249.56 | 13248.27 | 13250.85 | 3.00    | 13259.40  |
| 8   | 13100 | 13144.87 | 13175.89 | 13113.85 | -72.38  | 13253.85  |
| 9   | 13100 | 13113.46 | 13132.19 | 13094.73 | -43.70  | 13041.46  |
| 10  | 13100 | 13104.04 | 13112.48 | 13095.59 | -19.71  | 13051.03  |
| ⋮   | ⋮     | ⋮        | ⋮        | ⋮        | ⋮       | ⋮         |
| ⋮   | ⋮     | ⋮        | ⋮        | ⋮        | ⋮       | ⋮         |
| 55  | 16500 | 16681.41 | 16810.51 | 16552.31 | -301.23 | 17081.22  |

| $t$ | $Y_t$ | $S'_t$   | $S''_t$  | $a_t$    | $b_t$  | $F_{t+m}$ |
|-----|-------|----------|----------|----------|--------|-----------|
| 56  | 16700 | 16694.42 | 16729.25 | 16659.60 | -81.26 | 16251.08  |
| 57  | 16750 | 16733.33 | 16732.10 | 16734.55 | 2.85   | 16578.34  |
| 58  | 16750 | 16745.00 | 16741.13 | 16748.87 | 9.03   | 16737.40  |
| 59  | 16800 | 16783.50 | 16770.79 | 16796.21 | 29.66  | 16757.89  |
| 60  | 16950 | 16900.05 | 16861.27 | 16938.83 | 90.48  | 16825.87  |
| 61  | 17450 | 17285.01 | 17157.89 | 17412.14 | 296.62 | 17029.31  |
| 62  | 17700 | 17575.50 | 17450.22 | 17700.79 | 292.33 | 17708.76  |

### 3.3. Prediction Model with Holt's Double Exponential Smoothing

The Holt's Double Exponential Smoothing involved one smoothing iteration followed by forecasting. Prior to this, the combination value of smoothing parameter ( $\alpha$ ) and trend parameter ( $\beta$ ) must be determined to smooth the actual periodic time series data. Based on simulations, it acknowledged that combination value  $\alpha = 0.9$  and  $\beta = 0.1$  have a best prediction model based on MAPE values among others.

So that in this study, we performed experimental calculations using Holt's Double Exponential Smoothing method with  $\alpha = 0.9$  and  $\beta = 0.1$  for predict rice prices in Ambon City. The result is presented in **Table 3**.

**Table 3.** Calculation of forecast with Holt's Double Exponential Smoothing

| $t$ | $Y_t$ | $S'_t$   | $b_t$  | $F_{t+m}$ |
|-----|-------|----------|--------|-----------|
| 1   | 13150 | 13150.00 | 50.00  |           |
| 2   | 13200 | 13200.00 | 50.00  | 13200.00  |
| 3   | 13200 | 13205.00 | 45.50  | 13250.00  |
| 4   | 13250 | 13250.05 | 45.45  | 13250.50  |
| 5   | 13250 | 13254.55 | 41.36  | 13295.51  |
| 6   | 13250 | 13254.59 | 37.23  | 13295.91  |
| 7   | 13250 | 13254.18 | 33.46  | 13291.82  |
| 8   | 13100 | 13118.76 | 16.58  | 13287.65  |
| 9   | 13100 | 13103.53 | 13.40  | 13135.34  |
| 10  | 13100 | 13101.69 | 11.87  | 13116.93  |
| ⋮   | ⋮     | ⋮        | ⋮      | ⋮         |
| ⋮   | ⋮     | ⋮        | ⋮      | ⋮         |
| 55  | 16500 | 16568.94 | 16.89  | 17189.44  |
| 56  | 16700 | 16688.58 | 27.16  | 16585.83  |
| 57  | 16750 | 16746.57 | 30.24  | 16715.74  |
| 58  | 16750 | 16752.68 | 27.83  | 16776.82  |
| 59  | 16800 | 16798.05 | 29.58  | 16780.51  |
| 60  | 16950 | 16937.76 | 40.60  | 16827.64  |
| 61  | 17450 | 17402.84 | 83.04  | 16978.36  |
| 62  | 17700 | 17678.59 | 102.32 | 17485.88  |

### 3.4. Prediction Model with Damped Trend

The Damped Trend method involved one smoothing iteration followed by forecasting. Prior to this, the combination value of smoothing parameter ( $\alpha$ ), trend parameter ( $\beta$ ), and damped parameter ( $\varphi$ ) must be determined to smooth the actual periodic time series data. Based on simulations, it acknowledged that combination value  $\alpha = 0.9$ ,  $\beta = 0.9$ , and  $\varphi = 0.4$  have a best prediction model based on MAPE values among others.

So that in this study, we performed experimental calculations using Damped Trend method with  $\alpha = 0.9$ ,  $\beta = 0.9$ , and  $\phi = 0.4$  for predicted rice prices in Ambon City. The result is presented in **Table 4**.

**Table 4.** Calculation of forecast with Damped Trend

| $t$ | $Y_t$ | $S'_t$    | $b_t$    | $F_{t+m}$ |
|-----|-------|-----------|----------|-----------|
| 1   | 13150 | 13150.000 | 50.000   |           |
| 2   | 13200 | 13197.000 | 44.300   | 13170.000 |
| 3   | 13200 | 13201.472 | 5.797    | 13214.720 |
| 4   | 13250 | 13245.379 | 39.748   | 13203.791 |
| 5   | 13250 | 13251.128 | 6.764    | 13261.278 |
| 6   | 13250 | 13250.383 | -0.399   | 13253.833 |
| 7   | 13250 | 13250.022 | -0.341   | 13250.224 |
| 8   | 13100 | 13114.989 | -121.544 | 13249.886 |
| 9   | 13100 | 13096.637 | -21.378  | 13066.371 |
| 10  | 13100 | 13098.809 | 1.099    | 13088.086 |
| ⋮   | ⋮     | ⋮         | ⋮        | ⋮         |
| ⋮   | ⋮     | ⋮         | ⋮        | ⋮         |
| 55  | 16500 | 16559.606 | -485.646 | 17096.059 |
| 56  | 16700 | 16666.535 | 76.810   | 16365.347 |
| 57  | 16750 | 16744.726 | 73.444   | 16697.259 |
| 58  | 16750 | 16752.410 | 9.854    | 16774.104 |
| 59  | 16800 | 16795.635 | 39.296   | 16756.352 |
| 60  | 16950 | 16936.135 | 128.022  | 16811.354 |
| 61  | 17450 | 17403.734 | 425.960  | 16987.344 |
| 62  | 17700 | 17687.412 | 272.348  | 17574.118 |

### 3.5. Comparison of Prediction Accuracy

Mean Absolute Percentage Error (MAPE) is used to assess prediction accuracy. To identify the optimal model, prediction errors are calculated using MAPE values. The MAPE for Brown's Double Exponential Smoothing, Holt's Double Exponential Smoothing, and the Damped Trend method are computed based on **Eq. (12)**. The results of these MAPE calculations for the three methods are presented in **Table 5**.

**Table 5.** Calculation of MAPE value in each method

| Method                               | MAPE (%) |
|--------------------------------------|----------|
| Brown's Double Exponential Smoothing | 0.933    |
| Holt's Double Exponential Smoothing  | 0.903    |
| Damped Trend                         | 0.759    |

Based on **Table 5**, the Damped Trend method exhibited lowest prediction error with a MAPE value of 0.759%. Therefore, it could be concluded that the Damped Trend method, utilizing parameters  $\alpha$ ,  $\beta$ , and  $\phi$ , demonstrates the highest accuracy compared to the other methods.

### 3.6. Future Forecasting from Best Model

Since the Damped Trend method with parameters  $\alpha = 0.9$ ,  $\beta = 0.9$ , and  $\phi = 0.4$  yielded smallest prediction error, it was selected as the model for forecast rice prices in Ambon City over the next four periods: September to December 2025. Based on the latest data from **Table 4**, rice prices in Ambon City could be forecasted using the following model.

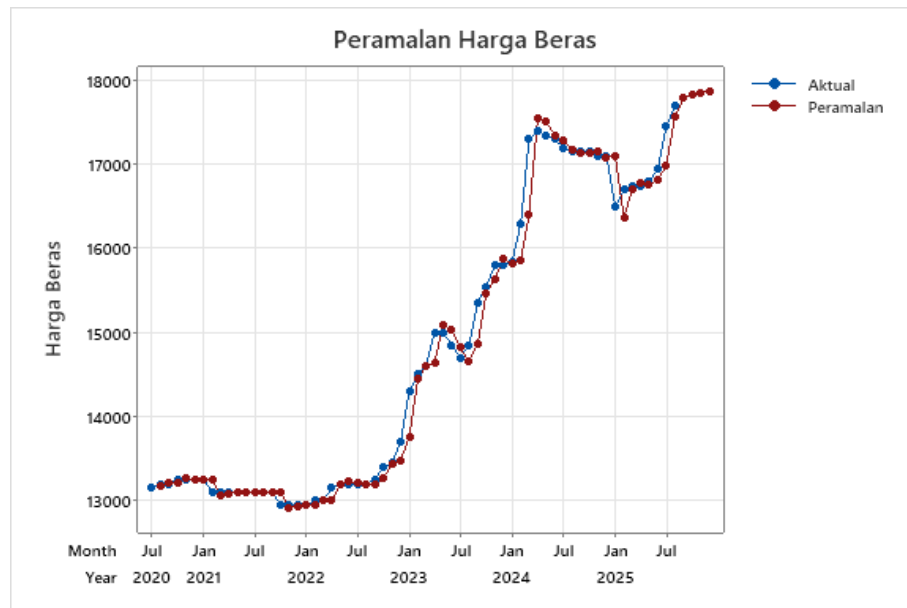
$$F_{t+1} = 17687,412 + (\varphi + \varphi^2 + \dots + \varphi^m) (272,348) \quad (13)$$

Once the forecasting model for rice prices in Ambon City is established, predictions for these periods are computed, with results presented in **Table 6**.

**Table 6.** Forecast of rice price using best model

| Month          | Price (IDR/kg) |
|----------------|----------------|
| September 2025 | 17,796.351     |
| October 2025   | 17,839.927     |
| November 2025  | 17,857.357     |
| December 2025  | 17,864.329     |

This forecast also could be described as graphic that showed in **Figure 2**.



**Figure 2.** Graphic of forecast for rice price in Ambon City 2020-2025 (*Application Source: R Software*)

Based on **Figure 2**, it demonstrated that the rice price forecasts generated by the optimal model exhibit high accuracy. This showed from the forecast line maintaining consistent alignment with the actual values, even tracking price spikes such as that observed in March 2024.

#### 4. Conclusions

This study demonstrates that the Damped Trend method with parameters with parameters  $\alpha = 0.9$ ,  $\beta = 0.9$ , and  $\varphi = 0.4$  outperforms both Brown's Double Exponential Smoothing and Holt's Double Exponential Smoothing for forecasting rice prices in Ambon City, achieving the lowest MAPE value. The forecasted rice prices for Ambon City from September to December 2025 using the optimal model are sequentially IDR 17,796/kg, IDR 17,839/kg, IDR 17,857/kg, and IDR 17,864/kg, indicating a modest monthly price increase. Based on these findings and conclusions, future researchers forecasting rice prices in Ambon City are advised to explore alternative methods, such as the Holt-Winters method or Artificial Neural Network approaches. It is also suggested to applying hybrid models combining Exponential Smoothing with machine learning techniques, such as Support Vector Regression (SVR) or Long Short-Term Memory (LSTM) networks, to better handle non-linear seasonal patterns.

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### Conflict of Interest

The authors declare that he/she has no conflicts of interest to report study.

### Declaration of Generative AI and AI-assisted technologies

Generative AI tools were used solely for language refinement (grammar, spelling, and clarity). The scientific content, analysis, interpretation, and conclusions were developed entirely by the authors. The authors reviewed and approved all final text.

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