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Forecasting Indonesia's Wholesale Price Index (WPI) Using the Holt's Exponential Smoothing Method

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Abstract

The Index of Wholesale Price (WPI) is a key benchmark in analyzing price movements at the wholesale level as it can affect the economic stability of a country. This research purpose to forecast the movement of WPI in Indonesia using Holt's Exponential Smoothing technique, which is effective in analyzing time series data that show trend patterns. This research utilizes secondary data obtained from the BPS for the period 2020-2024. The analysis is carried out by determining the optimal value of α and β parameters using trial and error techniques. Furthermore, the forecasting process is carried out using the best parameters that have been obtained. Based on the analysis results, the combination of parameters $\alpha = 0.9$ and $\beta = 0.8$ provides a Mean Absolute Percentage Error (MAPE) value of 0.22%, which indicates a very good level of forecasting accuracy. WPI forecasting for the year 2025 shows a consistent upward pattern, reflecting a consistent increase in WPI previous historical trends. The results of this study can be a reference in making price and wholesale trade policies by the government and related parties in the economic sector.

Keywords: Holt's Exponential Smoothing, Forecasting, Wholesale Price Index, MAPE.

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1. Introduction

The economic stability of a country is influenced by the dynamics of the prices of goods and services in the market. Significant price changes can have an impact on inflation, people's purchasing power, and economic policy (Yanovitzky & VanLear, 2018). One important indicator in analyzing price movements is the Wholesale Price Index (WPI). WPI aims to measure the extent to which commodity prices change at the wholesale trade level in a particular country or region. According to Statistics Indonesia, there has been an increasing trend in the development of WPI in Indonesia over the past few years (Kurniawan & Kadir, 2023). In December 2024, the national general WPI increased by 1.98% compared to December 2023, with the highest increase occurring in the industrial sector by 2.12% (Man et al., 2020). Cooking oil, palm oil, filter clove cigarettes, cocoa, and coffee were the commodities that contributed to the increase. To anticipate price spikes at the wholesale level in coming years, the government needs to evaluate the factors that influence WPI increases and forecast future movements (Arindra Zainal, 2012).

The exponential smoothing method is forecasting the moving average by weighting it down exponentially to past observations' value (Indriana and Anjasari, 2018). This method consists of two types, including single exponential smoothing and double exponential smoothing. The single exponential smoothing method is used if the time series data does not containtrend and seasonal patterns (Lase & Harefa, 2025). In contrast, the double exponential smoothing method is used if the time series data contains trend patterns and does not contain seasonal patterns (Nurhamidah et al., 2020). One of the most popular forecasting techniques used is Holt's Exponential Smoothing method.

The Holt-Winters Exponential Smoothing method is a forecasting method that not only looks at trend factors, but also looks at seasonal factors (Hernandy et al., 2021). If the data contains trend and seasonality components, the Holt-Winters Exponential Smoothing method can be used, which requires three smoothing parameters (Agusdin et al., 2024). This technique is suitable when the data used shows a trend pattern. This approach is similar to simple exponential smoothing, but has two main components that are updated every period, namely the level and trend components

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(Agusman, 2023). The level component represents the adjusted data value at the end of each period, while the trend is an adjusted forecast to show the average growth at the end of each period. This method performs continuous forecasting by gradually updating the data. This process uses the parameter α, whose value is in the range between 0 and 1(Ishak et al., 2022).

Recently, various studies have applied Holt's Exponential Smoothing method or Holt Type Double Exponential Smoothing for forecasting. The results (Wasono et al., 2024) showed excellent forecasting ability with a MAPE value below 10%. In addition, research which aims to forecast the demand for PT Petrogas Prima Services LPG gas cylinders using three methods, namely Moving Average, Single Exponential Smoothing, and Double Exponential Smoothing. The results (Septiana, 2024) showed Results indicate that additive method of Holt-Winterexponential 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.

2. Literature Review

2.1. Time Series

Time series analysis is a statistical technique used to process observational data arranged in a specific time sequence. This technique serves to forecast future observation values due to the relationship between previously collected data (Box.et.al, 2019). The main objectives of this analysis include forecasting (predicting) future values, modeling, depicting, and extracting information from data) (Charlton et al., 2022). Time series analysis has several main components, namely trends (long-term patterns of increase or decrease), seasonality (patterns that repeat periodically), cycles (long-term fluctuations due to economic or social factors), and random fluctuations (unpredictable variations) (Shu & Chan, 2025).

2.2. Holt's Exponential Smoothing

One approach to time series data proposed by Charles Holt in 1957 is Holt's Exponential Smoothing method. This method is applied when historical data shows a trend element Holt's Exponential Smoothing performs smoothing twice (Binoto & Santi, 2025). Thus, to perform forecasting in the next period, it is necessary to forecast with an updated smoothing value and trend estimation using the following formula (Pleños, 2022):

- Level Smoothing:

$$S_t = \alpha X_t + (1-\alpha)(S_{t-1} + G_{t-1}) \tag{2.1}$$

- Trend Smoothing:

$$G_t = \beta(S_t - S_{t-1}) + (1-\beta)G_{t-1} \tag{2.2}$$

To estimate two smoothing values S_t dan G_t, the following equation is used:

- Initialize S_t

$$S_t = X_t \tag{2.3}$$

- Initialize G_t

$$G_t = X_t - X_{t-1} \tag{2.4}$$

The forecasting value for time *t* in Holt's Exponential Smoohting is given in formula below (Komang et al., 2023):

$$F_t = S_t + G_t \tag{2.5}$$

where:

X_t	=	Actual data in period t
n	=	Number of periods to be predicted ahead
α	=	Smoothing coefficient for level ($0 < \alpha \leq 1$)
β	=	Smoothing coefficient for trend ($0 < \beta \leq 1$)
S_t	=	Smoothing value for the t th period level
G_t	=	Smoothing value for period-t trend

2.3. Wholesale Price Index (WPI)

The Index of Wholesale Prices (WPI) is a method for calculating changes in the average value of prices of various goods in wholesale transactions over a certain period of time. This index serves as a key measure in assessing economic development as well as a market and financial analysis tool. WPI reflects changes in wholesale trade prices in Indonesia and serves as an indicator of the flow of goods and money within the country, the calculation of WPI is expressed in the following formula (Lamba, 2016):

$$IHPB_t = \left(\frac{P_t}{P_{t-1}}\right) \times \left(\frac{P_{t-1}Q_0}{P_0Q_0}\right) \times 100 \quad (2.7)$$

where:

$IHPB_t$	=	WPI in period t
P_t	=	Commodity price in period t
P_{t-1}	=	Commodity price in the previous period t-1
P_0Q_0	=	Scale value in the base year
$P_{t-1}Q_0$	=	The value of the scales in the previous period

2.4. Mean Absolute Percentage Error (MAPE)

Mean Absolute Percentage Error (MAPE) is an evaluation measure that measures the average of the absolute percentage error between the predicted value and the actual value (Arisoma et al., 2019). The calculation of the MAPE value can be done using the following formula (Prayudani et al., 2019):

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{y_i - \hat{y}_i}{y_i}\right| \times 100\% \quad (2.8)$$

Where:

y_i	=	The i-th actual value
$\hat{y}_i$	=	The i-th estimated value
n	=	Total data

The evaluation criteria for the MAPE value can be seen in the following table (Farafisha, 2022):

Table 1. MAPE Value Evaluation Criteria

MAPE Value	Criteria
MAPE $<$ 10%	Excellent forecasting results
10% $\leq$ MAPE $<$ 20%	Good forecasting results
20% $\leq$ MAPE $<$ 50%	Viable forecasting results
MAPE $\geq$ 50%	Poor forecasting results

3. Research Method and Materials

3.1. Type of Research

This research uses quantitative research, focusing on the collection and analysis of numerical data. The data is then processed statistically to produce objective and measurable findings.

3.2. Data Source

In this study, secondary data is used, which is data obtained from sources that have been collected by other parties for specific purposes and are publicly available. The data source used comes from the official website of the Central Statistics Agency (BPS), namely monthly WPI data for the period 2020-2024.

3.3. Research Variable

The Index of Wholesale Prices (WPI) is an economic variable applied in this study to understand price trends in the wholesale trade sector. WPI calculates the average price change of goods and services over time at the wholesale trade level. Addition, this index provides important information for governments, businesses, and investors involved in economic decision-making.

3.4. Data Analysis Technique

Data analysis in this study used the following techniques:

a. Inputting data for the Wholesale Price Index in Indonesia from 2020-2024 in RStudio software.
b. Perform descriptive statistics of the Wholesale Price Index data in Indonesia.
c. Identify the data by plotting the time series.
d. Determine the initial value (initialization).
e. Determine the optimum value of Alpha and Beta parameters.
f. Calculating the smoothing value.
g. Perform forecasting using the best smoothing parameters.
h. Test the accuracy of the forecasting results by using the MAPE value calculation.

4. Results and Discussion

4.1. Descriptive Analysis

Descriptive analysis is used to provide a general explanation of the characteristics of the data being analyzed. In this study, descriptive statistics are used to understand the movement pattern of the Wholesale Price Index in Indonesia during the 2020-2024 period. The results of the descriptive analysis are presented in Table 2.

Table 2. Descriptive Statistics

Variable	Total Data	Minimum	Average	Maximum
WPI	60	103.0	111.2	119.8

Based on Table 2, the amount of data used for analysis consists of 60 observations; the annual average WPI in Indonesia from 2020-2024 is 111.2. The smallest WPI value of 103.0 occurred in January 2020 while the highest value reached 119,8 in December 2024.

4.2. Time Series Plot

The first step before analyzing the data using Holt's exponential smoothing method is to make a time series plot to determine whether the data to be analyzed is suitable for using Holt's exponential smoothing method. The results of the time series plot of WPI data in Indonesia can be seen in Figure 1.

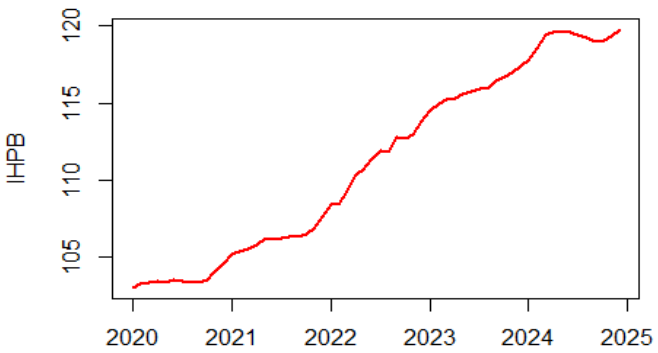

Figure 1. Time Series Plot of WPI

Based on Figure 1, it can be seen that the Wholesale Price Index in Indonesia has a trend data pattern because it has a gradual increase in the period 2020-2024. So, the forecasting method that can be used is Holt's Exponential Smoothing.

4.3. Holt's Exponential Smoothing Analysis

4.3.1. Determining the Initial Value (Initialization)

To start the smoothing process, the initialization stage is performed first. Equation (2.3) is used to calculate the level component and Equation (2.4) is used to obtain the trend component. The following are the initial calculation results obtained through a manual process in the initialization stage of Holt's Exponential Smoothing method.

a. Initialization of level components:

$$S_2 = X_2 = 103.29$$

b. Initialize the trend components:

$$G_2 = X_2 - X_1 = 103.29 - 103.04 = 0.25$$

4.3.2. Determining the Optimum Value of Alpha & Beta Parameters

The Holt's Exponential Smoothing method uses 2 smoothing parameters, namely α (alpha) and β (beta) which are calculated by trial error method between the values of 0 to 1 so that 100 model combinations are obtained. After the models were tested, the model with the lowest MAPE value was determined as the most optimal model for forecasting. The results of the optimal model selection can be found in Table 3.

Table 3. Combination of α and β Parameter Values for the Smallest MAPE

Alpha (α)	Beta (β)	MAPE (%)
0.1	0.1	0.78
0.5	0.7	0.28
0.3	0.4	0.43
0.9	**0.8**	**0.22**
0.4	0.7	0.34
0.3	0.2	0.43
0.8	0.1	0.26
0.6	0.4	0.28
⋮	⋮	⋮
1.0	1.0	0.24

The lowest MAPE value is obtained when the parameters α = 0.9 and β = 0.8, which is 0.22% as shown in Table 3. Thus, this parameter combination is considered optimal and is used in the forecasting process using Holt's Exponential Smoothing method.

4.3.3. Calculation of Smoothing Value

The optimal parameters obtained through simulation (trial and error) are used to obtain the level and trend smoothing values. The calculation is based on Equation (2.1) and Equation (2.2) with parameters α = 0.9 and β = 0.8. The results of the level and trend smoothing calculations can be seen in Table 4.

Table 4. Level & Trend Smoothing Values

Period	Level	Trends
March 2020	103.2900	0.2500
April 2020	103.4050	0.1420
May 2020	103.4777	0.0866
June 2020	103.3894	-0.0533
July 2020	103.5196	0.0935
August 2020	103.4663	-0.0239
September 2020	103.3862	-0.0689
October 2020	103.3557	-0.0382
November 2020	103.5448	0.1436
December 2020	104.0228	0.4112
January 2021	104.6014	0.5451
February 2021	105.1946	0.5836
March 2021	105.4378	0.3113
⋮	⋮	⋮
December 2024	119.2799	0.2156

4.3.4. Forecasting Calculation

After the data smoothing is completed, the next step is to perform forecasting for the period January 2025 to December 2025 by applying Equation (2.6), so that the results of forecasting the value of WPI in Indonesia are presented in Table 5 below.

Table 5. WPI Data Forecasting Results for The Next 12 Periods

Period	Forecasting
January 2025	120.1881
February 2025	120.6157
March 2025	121.0433
April 2025	121.4709
May 2025	121.8985
June 2025	122.3260
July 2025	122.7536
August 2025	123.1812
September 2025	123.6088
October 2025	124.0364
November 2025	124.4640
December 2025	124.8915

The following is a plot of WPI forecasting results in Indonesia using optimal parameters.

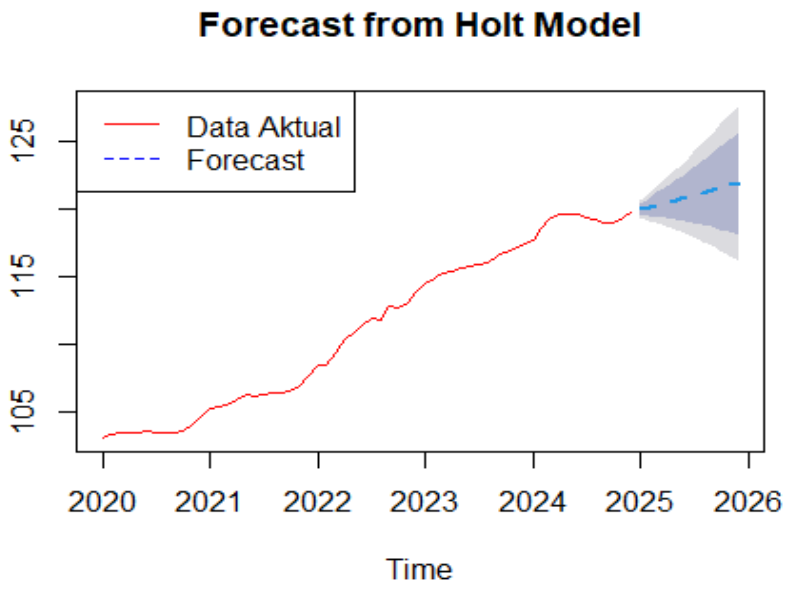

Figure 2. Plot of Indonesia WPI Forecasting Results

Figure 2 shows that the red line shows the actual data, while the dashed blue line is the result of forecasting for the next 12 periods. The results of WPI forecasting in Indonesia are expected to increase from the beginning of 2025 to the end of 2025. This pattern reflects a trend that follows the movement of previous historical data. The results of WPI forecasting in the future can at least give an idea to the government and business actors about the conditions that will occur in the future.

4.3.5. MAPE Calculation

This study uses the accuracy test of forecasting results through the calculation of Mean Absolute Percentage Error. (MAPE) in accordance with Equation (2.8). Meanwhile, the results of the MAPE calculation can be found in Table 6.

Table 6. MAPE Value

MAPE Value
0,22

Based on Table 6, the MAPE error value is 0.22%. Therefore, based on Table 1, forecasting using Holt's Exponential Smoothing technique has a very good level of accuracy because the resulting MAPE value is below 10%.

5. Conclusion

Based on the research results, it can be concluded that forecasting with Holt's Exponential Smoothing method to forecast the Index of Wholesale Price (WPI) in Indonesia produces optimal parameter values, namely $\alpha = 0.9$ and $\beta = 0.8$ with a MAPE value of 0.22%. The MAPE value shows very good forecasting results. These results help governments and businesses make good economic policies and business strategies to anticipate price changes.

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