Engineering and Technology Journal e-ISSN: 2456-3358

Volume 10 Issue 06 June-2025, Page No.- 5514-5517

DOI: 10.47191/etj/v10i06.26, I.F. – 8.482

Application of the Holt-Winters Method in Bond Yield Analysis and Prediction Using R

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ABSTRACT: Forecasting bond yields is done with the Holt-Winters method using the R application. The data used were obtained from the Investasi.id website with the period January 2013 to December 2022. Two models are applied in this study, namely Holt-Winters Additive and Holt-Winters Multiplicative. To assess the accuracy of the forecasting results, Mean Absolute Error (MAE) is used. The results show that both models are able to produce fairly accurate predictions with low MAE values. The Holt-Winters Multiplicative model is slightly superior to the Additive model, but the difference is not too large. Therefore, the Holt-Winters method can be used as a reliable approach in analyzing and predicting bond yields to aid decision-making in finance.

KEYWORDS: Holt-Winters, Bond Yield, MAE

INTRODUCTION

Bonds are one of the investment instruments that provide fixed income to investors through coupon payments and return of principal value at maturity [1]. One of the main factors considered in bond investment decisions is the bond yield, which reflects the level of profit obtained from the investment. Bond yields are influenced by various factors, including interest rates, credit risk, inflation, and overall financial market conditions [2]. Thus, bond yield analysis and forecasting play an important role in helping investors and analysts make more accurate investment decisions.

In financial analysis, time series forecasting methods are often used to predict the movement of bond yields based on historical data [3][4]. One commonly used method is Holt- Winters Exponential Smoothing, a forecasting technique that considers trends and seasonal patterns in the data. This method has the advantage of capturing long-term pattern changes as well as periodic fluctuations, thus being able to produce more accurate predictions compared to simple forecasting methods. Holt Winter's statistical modeling of two variables will be used to guarantee accurate forecasting. It accurately generates comparable annual data for the three nations. Likewise, that might act as a strong starting point for using measurable displaying to gauge the zakat gathered in the resulting five and a decade. The zakat revenue will continue to significantly rise in each nation as the study concludes. This result also indirectly demonstrated that businesses in every nation will be able to combine zakat as a blessing without experiencing deflation in Southeast Asia [5]

This research aims to analyze and predict bond yields using the Holt-Winters method with the R application and evaluate the accuracy of the prediction results. The results of this study are expected to provide insight for investors, financial analysts, and policy makers in understanding the pattern of bond yields. In addition, this research is also useful for students as a reference in studying time series forecasting and the application of statistical methods in financial data analysis.

RESEARCH METHODS

This research uses bond yield data obtained from the official website Investasi.id covering the period January 2013 - December 2022. This data is analyzed to understand historical patterns and used in the forecasting process.

1. Holt-Winters Method

The Holt-Winters Exponential Smoothing method is applied in this study as a time series forecasting technique. This method is able to capture changes in data patterns over time by considering the baseline value of the data, the tendency of changes in the long term, as well as repetitive patterns that occur periodically.

Holt-Winters consists of two main models, namely additive and multiplicative [6].

1.1 Holt-Winters Additive

Holt-Winters Additive is a time series forecasting method used when seasonal data shows fluctuations that appear relatively stable [3]. The Holt-Winters Additive method uses three equations, namely:

a) Level Smoothing

$$L_t = \alpha(Y_t - S_{t-s}) + (1-\alpha)(L_{t-1} + b_{t-1})$$

b) Trend Smoothing

$$b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1}$$

c) Seasonal Smoothing

$$S_t = \gamma(Y_t - L_t) + (1-\gamma)S_{t-c}$$

Forecasting

$$F_{t+m} = L_t + b_t m + S_{t-s+m}$$

Description:

α : Parameters for level smoothing, $0 \leq \alpha \leq 1$

β : Parameters for trend smoothing, $0 \leq \beta \leq$

γ : Parameters for seasonal smoothing, $0 \leq \gamma \leq 1$

s : Seasonal length

m : Number of future periods to be estimated

Y_t : Actual data in period t

L_t : Level smoothing in period t

b_t : Trend smoothing in period t

S_t : Seasonal smoothing in period t

F_{t+m} : Forecasting in period (t + m)

b) Trend Smoothing

$$b_t = \beta(S_t - S_{t-1}) + (1-\beta)b_{t-1}$$

c) Seasonal Smoothing

$$I_t = \gamma\frac{X_t}{S_t} + (1-\gamma)I_{t-L}$$

Forecasting

$$F_{t+m} = (S_t + b_{t+m})I_{t-L+m}$$

Description:

α : Parameters for level smoothing, $(0 < \alpha < 1)$

β : Parameters for trend smoothing, $(0 < \beta < 1)$

γ : Parameters for seasonal smoothing, $(0 < \gamma < 1)$

2. Mean Absolute Error (MAE)

Mean Absolute Error (MAE) is one of the methods used to measure the accuracy of a forecasting model. The MAE value shows the average absolute error between the forecasting results and the real value [8]. The equation used by MAE is as follows:

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|f_i - y_i|$$

Description:

f_i : Forecasting result value

y_i : Actual value

n : Number of data

1.2 Holt-Winters Multiplicative

The Holt-Winters Multiplicative method is a time series forecaster that is used if the plot and original data show seasonal fluctuations that vary [7]. The Holt-Winters Multiplicative method uses three equations, namely:

a) Level Smoothing

$$S_t = \alpha\frac{X_t}{I_{t-L}} + (1-\alpha)(S_{t-1} + b_{t-1})$$

X_t : Tth data

S_t : T-th exponential smoothing

S_{t-1} : Exponential smoothing to (t-1)

S_L : Entry-level smoothing

b_t : T-period trend smoothing

b_{t-1} : Period (t-1) trend smoothing

b_L : Initial trend smoothing

I_t : Seasonal smoothing

I_{t-L} : Seasonal smoothing t = 1, 2, ..., t-L

L : Seasonal Length

F_t : Forecasting value in period t

F_{t+m} : Forecasting value m periods ahead

m : Forecasting m periods ahead

RESULTS AND DISCUSSION

Indonesian Bond Yield data from 2013 to 2023 obtained from the official website of Investasi.id. The data is displayed in R software as in Figure 1.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	5307	5616	5917	5962	6516	6112	5686	6247	5973	5705	5429	5167
2014	5343	5416	5522	5494	6099	7116	7871	8611	8490	7416	8691	8440
2015	8887	8389	7969	7934	8061	8241	8025	8220	8397	8049	7696	7793
2016	7041	6902	7411	7692	8166	8380	8603	8786	9624	8803	8605	8872
2017	8277	8244	7713	7715	7865	7462	6944	7138	7069	7259	8184	7941
2018	6318	6595	6669	6906	7060	7803	7755	8127	8208	8601	7866	7997
2019	8051	7801	7665	7810	8023	7369	7378	7354	7296	7005	7074	7047
2020	6645	6887	7907	7892	7340	7215	6825	6864	6930	6609	6188	5942
2021	6257	6598	6814	6476	6445	6630	6307	6077	6353	6169	6267	6368
2022	6449	6510	6749	6998	7047	7249	7197	7117	7380	7541	6949	6925

Figure 1. Indonesian Bond Yield Data

1. Modeling Method

At this stage, the data that has been obtained will be modeled using the Holt-Winters Additive and Multiplicative forecasting method. By using a seasonal period of 12 which shows the number of months in 1 year.

2. Model Evaluation

Model evaluation is done to assess the extent to which the Holt-Winters method can accurately predict inflation. The following forecasting results with actual data comparison graphs are displayed as Figure 2.

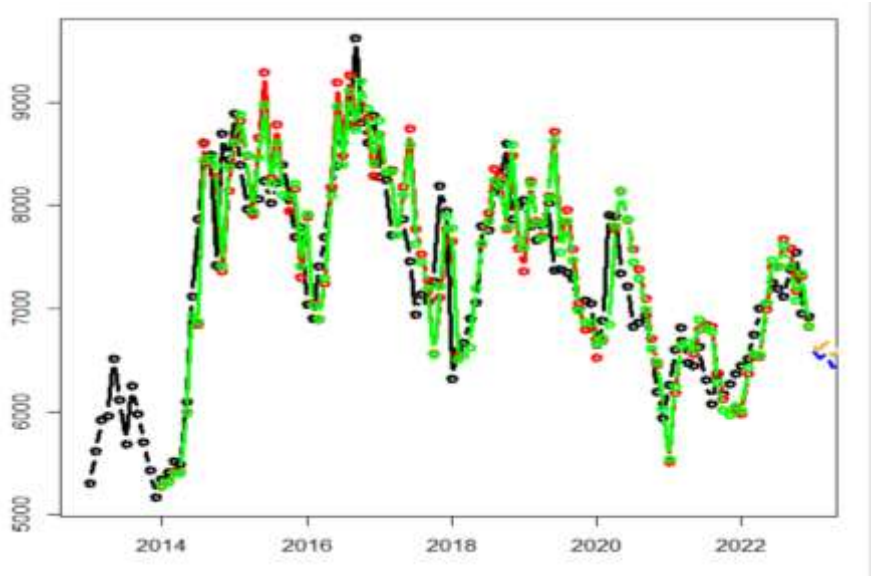

Figure 2. Comparison of Forecasting Results with Actual Data

Description:
Black : Actual Data;
Green : Holt-Winters Additive;
Red : Holt-Winters Multiplicative;
Oren : Additive Forecasting Results;
Blue : Multiplicative Forecasting Results.

From Figure 2, the comparison graph of bond yield data forecasting results with actual data using the Holt-Winters method in the Additive and Multiplicative models shows that the forecasting results are close to the actual data. For forecasting results for the next 12 months with the Holt-Winters method in the Additive model, it is shown in Table 1.

Table 1. Forecasting Results with the Holt-Winters Additive Method

Month-	**1**	**2**	**3**	**4**	**5**	**6**
Forecast	6578.078	6514.555	6581.406	6437.973	6431.794	6717.744

Month-	**7**	**8**	**9**	**10**	**11**	**12**
Forecast	6822.266	7168.388	7603.656	7457.147	7161.639	7051.874

As for the forecasting results for the next 12 months with the Holt-Winters method on the Multiplicative model can be seen in Table 2.

Table 2. Forecasting Results with the Multiplicative Holt-Winters Method

Month-	**1**	**2**	**3**	**4**	**5**	**6**
Forecast	6635.267	6611.046	6683.292	6540.188	6585.892	6966.903

Month-	**7**	**8**	**9**	**10**	**11**	**12**
Forecast	7079.346	7425.577	7713.191	7474.407	7218.071	7116.979

3. Analysis of Results

The forecasting results with the Holt-Winters Additive and Multiplicative forecasting models have the same excellent MAE values. These values are shown in Table 3.

Table 3. Analysis of Results

Forecasting Methods	MAE Value
Holt-Winters Additive	354.9695
Holt-Winters Multiplicative	384.4882

CONCLUSIONS

Based on the research results, the Holt-Winters Additive and Holt-Winters Multiplicative methods can be used to forecast bond yields with a fairly good level of accuracy. However, the Holt-Winters Additive method more effective than the Holt-Winters Multiplicative method, because it has a smaller Mean Absolute Error (MAE) value (354.9695 compared to 384.4882). This shows that the Additive method is better able to capture trend and seasonal patterns in bond yield data, thus providing more accurate forecasting results.

Therefore, the Holt-Winters Additive method can be a better choice for analysis and decision-making in bond investments.

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