Volume. 7 No 1 June (2024)

e-ISSN: **2615-3270**
p-ISSN: **2615-3599**

Eigen Mathematics Journal

Homepage jurnal: http://eigen.unram.ac.id

# Forecasting Coffee Exports to the United States Using the Smoothing Holt-Winters Exponential Method

***Wahyu Nur Achmadin[a,*], Dwi Agustin Retnowardani[b], Dewi Mashitasari[c] , Fita Fatimah[d]***

a. Program Studi Statistik, Fakultas Sains dan Teknologi, Universitas PGRI Argopuro Jember, Jawa Timur, Indonesia. Email: wahyu.achmadin@gmail.com
b. Program Studi Statistik, Fakultas Sains dan Teknologi, Universitas PGRI Argopuro Jember, Jawa Timur, Indonesia. Email: 2i.agustin@gmail.com
c. Program Studi Statistik, Fakultas Sains dan Teknologi, Universitas PGRI Argopuro Jember, Jawa Timur, Indonesia. Email: sarishita0423@gmail.com
d. Program Studi Statistik, Fakultas Sains dan Teknologi, Universitas PGRI Argopuro Jember, Jawa Timur, Indonesia. Email: fita.fatimah88@gmail.com

## ABSTRACT

A study was conducted to estimate coffee exports to the United States using the Holt-Winters Exponential method. The aim of this research is to project coffee export activity over the next four years. Data on coffee exports to the United States from 2000 to 2022 was obtained from the Indonesian Central Bureau of Statistics and used as a research object. The range of values used in this study is between 0.1 and 0.5 for α, between 0.1 and 0.5 for β, and between 0.1 and 0.9 for ϒ. The results of this research state that it is estimated that in 2023, Indonesia will export coffee to the United States amounting to 61,332.60 tons, in 2024 amounting to 60,661.50 tons, in 2025 amounting to 61,563.27 tons, and in 2026 amounting to 60,196.50 tons.

Keywords: Coffee, Exports, Forecasting, Holt-Winters Exponential Method, United States

Diserahkan: 15-03-2024; Diterima: 08-05-2024; Doi: https://doi.org/10.29303/emj.v7i1.202

## 1. Introduction

Trade is an opportunity to achieve profits, and with the rise of international trade in the current global economic situation, competition between international traders is increasingly fierce, requiring development in international trade. The benefits of this trade include increased income, foreign exchange reserves, capital transfer, and increased employment opportunities.

Data from the Central Statistics Agency shows that coffee exports to the US reached over 2.5 million tons last year, marking the highest record in the past decade. This reflects the positive impact of coffee farmers' efforts to improve the quality of their products and effective marketing strategies in entering the demanding US market. Along with this, the demand for organic and sustainable coffee has also become an important factor influencing consumption patterns in the US, with consumers paying increasing attention to the social and environmental aspects of the products they purchase.

Various promotional activities and consumer education on organic certification and sustainable practices have driven the growth of the environmentally friendly coffee market. Additionally, changing consumption trends, such as increased interest in specialty coffee and single-origin coffee, have opened up new opportunities for coffee producers from various countries to enter the competitive US market. The article also highlights the important role of trade agents and distributors in facilitating coffee exports to the US by introducing new products to coffee enthusiasts across the country.

However, there are challenges faced by the coffee industry in dealing with price fluctuations and intense market competition, especially from emerging local coffee brands in the US. Additionally, political uncertainty and international

* Corresponding author.
Alamat e-mail: *wahyu.achmadin@gmail.com*

trade regulations can also affect the flow of coffee trade between producing and consuming countries. Despite these challenges, the prospects for coffee exports to the United States remain bright, with the potential for sustainable growth alongside increasing consumer demand for high-quality and sustainable coffee.

Forecasting is a method for predicting future events. Each forecasting method will provide accurate results if the forecaster can identify the factors that influence the selection of the forecasting model (Handika & Satwika, 2023; Nurhamidah et al., 2020; Pleños, 2022). These factors include identifying and understanding historical patterns in data as well as time horizons (Dewi & Listiowarni, 2020). An effective forecasting method is one that produces forecasts close to actual values or minimizes prediction errors.

One method of forecasting time series data that is commonly used is the smoothing exponential method (Aini et al., 2022; Caspah, 2017; Pleños, 2022). This method consists of three types, namely single exponential smoothing, double exponential smoothing, and triple exponential smoothing (Andriani et al., 2022). Single exponential smoothing is used for time series data that has no trend or seasonality. Double exponential smoothing is used for time series data that only has a trend, and is divided into two types, namely Brown's double exponential smoothing and Holt's double exponential smoothing. According to the research on forecasting the number of leprosy sufferers using double exponential averaging, the Holt method produces more accurate results because it has a smaller prediction error compared to the Brown method.

The triple exponential smoothing method is used to forecast time series data that has trend and seasonal elements simultaneously. There are two types of triple exponential smoothing methods, namely Brown's triple exponential smoothing and Holt-Winters triple exponential smoothing. The use of the Smoothing Holt-Winters exponential method is more accurate than ARIMA because it produces a smaller prediction error (Efrilia, 2021).

Several researchers have used the Holt-Winters Exponential Smoothing method to forecast, such as forecasting in the sales system (Hariri & Prakasa, 2023), Inflation (Caspah, 2017), industry [2], tourism (Febriyanti & Rifai, 2022; Mendila et al., 2023), export (Andriani et al., 2022), business (Rahman et al., 2018; Siregar et al., 2021; Utami & Atmojo, 2017) and currency(Atoyebi et al., 2023)

## 2. Research Methods

The following are the forecasting steps carried out in this research:

1. Secondary Data Collection: The initial stage in the forecasting process involves gathering historical data on coffee exports to the United States. This data can be obtained from reliable sources such as the Central Statistics Agency of the Republic of Indonesia. Historical data is essential for building an accurate and relevant forecasting model.
2. Data Plot Graph Creation: After historical data has been collected, the next step is to create data plot graphs. These graphs will aid in visualizing trends, seasonal patterns, and data fluctuations over time. By examining the data plot graphs, researchers can identify patterns that may exist in the data, such as upward or downward trends, or seasonal cycles.
3. Identification of Key Formulations: The Holt-Winters Exponential Smoothing method involves the use of important mathematical formulas for forecasting. These formulas include calculations for level ($\alpha$), trend ($\beta$), and seasonality ($\gamma$). Identification and a good understanding of these formulas are crucial to comprehend how the forecasting model works and how to modify it according to the data characteristics.
4. Adjustment of Alpha, Beta, and Gamma Values: After identifying the formulas, the next step is to adjust the values of alpha, beta, and gamma. These values control how much weight is given to the most recent observations, trends, and seasonality in the forecasting model. Adjusting these values is important to ensure that the forecasting model provides optimal results that align with the given data.
5. Search for the Smallest Mean Squared Error (MSE) Value: Once the forecasting model is built and the appropriate parameters are set, the next step is to search for the smallest Mean Squared Error (MSE) value. MSE is an evaluation metric used to measure how well the forecasting model fits the historical data. By searching for the smallest MSE value, we can identify the parameters that provide the most accurate forecasting results.
6. Forecasting: After determining the optimal parameters, the final step is to conduct the forecasting using the adjusted Holt-Winters model. Forecasting is done by projecting the level, trend, and seasonality values into the future based on the available historical data. The forecasting results can then be used to make relevant decisions in production planning, inventory management, and marketing strategies.

## 3. Results and Discussion

This research began by converting all the data into graphs. The data presented in this research covers the value of Indonesian coffee exports to the United States from 2000 to 2022, with a range of years per year. This data was obtained from the Indonesian Central Statistics Agency

The graph produced from the data shows an unstable fluctuation pattern (evolving up and down). This variation is caused by seasonal factors that influence each data. Figure 1.

In the forecasting process, there are four main components that form the basic structure, namely level, trend, seasonality, and prediction. In this research, to determine the level, the equation is used :

$$L_t = \alpha \times \left( \frac{y_t}{S_{t-s}} \right) + (1-\alpha) \times (L_{t-1} + T_{t-1}) \quad (1)$$

Meanwhile, to determine the trend value, the equation is used:

$$T_t = \beta \times (L_t - L_{t-1}) + (1-\beta) \times T_{t-1} \quad (2)$$

And to determine seasonal values, the equation is used:

$$S_t = \gamma \times \left( \frac{y_t}{L_t} \right) + (1-\gamma) \times S_{t-s} \quad (3)$$

And to determine the predicted value is

$$y_{t+k} = (L_t + k \times T_t) \times S_{t+k-s} \quad (4)$$

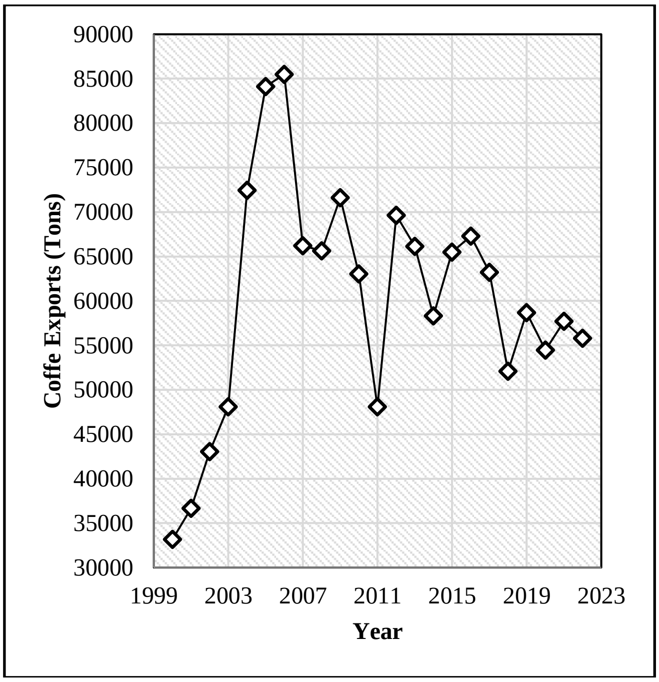


**Figure 1.** Data results graph

with the components α, β, and ϒ being independent. The range of values used in this study is between 0.1 and 0.5 for α, between 0.1 and 0.5 for β, and between 0.1 and 0.9 for ϒ.

After the calculation results are obtained, the error value is calculated by dividing the actual data value at a certain time interval by the predicted results. After this calculation is carried out, there is still a negative error value. Therefore, to obtain the mean absolute error value, the absolute value of the resulting error is needed. In addition, the Mean Squared Error value is calculated by squaring the average absolute error value. The Mean Squarred Equation (MSE) calculation results are displayed in table 1-5. Tabel 1. Parameter pada saat $\alpha$ = 0.1

**Table 1.** Parameter at time α = 0.1

| Mean Squared Error | | β | | | | |
|---|---|---|---|---|---|---|
| | | **0.1** | **0.2** | **0.3** | **0.4** | **0.5** |
| $\gamma$ | 0.1 | 2172.51* | 1664.8*5 | 1339.88* | 1145.93* | 1038.28* |
| | 0.2 | 1797.00* | 1407.47* | 1158.94* | 1011.01* | 929.26* |
| | 0.3 | 1519.95* | 1222.48* | 1032.00* | 917.91* | 854.27* |
| | 0.4 | 1313.60* | 1088.04* | 942.40* | 854.08* | 803.98* |
| | 0.5 | 1159.49* | 990.16* | 879.65* | 811.70* | 772.52* |
| | 0.6 | 1045.28* | 919.92* | 837.33* | 786.05* | 756.31* |
| | 0.7 | 962.71* | 871.82* | 811.74* | 774.51* | 753.37* |
| | 0.8 | 906.36* | 842.65* | 801.00* | 775.96* | 762.88* |
| | 0.9 | 872.84* | 830.83* | 804.54* | 790.27* | 784.85* |

* in millions

**Table 2.** Parameter at time α = 0.2

| Mean Squared Error | | β | | | | |
|---|---|---|---|---|---|---|
| | | **0.1** | **0.2** | **0.3** | **0.4** | **0.5** |
| $\gamma$ | 0.1 | 1071.20* | 822.35* | 721.22* | 679.12* | 658.27* |
| | 0.2 | 927.40* | 730.76* | 651.87* | 620.59* | 606.89* |
| | 0.3 | 826.58* | 668.84* | 605.56* | 581.71* | 573.36* |
| | 0.4 | 755.41* | 627.89* | 576.42* | 558.16* | 554.04* |
| | 0.5 | 705.10* | 602.07* | 560.33* | 546.78* | 546.23* |
| | 0.6 | 669.99* | 587.55* | 554.43* | 545.28* | 548.01* |
| | 0.7 | 646.57* | 581.93* | 556.88* | 552.10* | 558.00* |
| | 0.8 | 632.79* | 583.83* | 566.51* | 566.16* | 575.18* |
| | 0.9 | 627.58* | 592.60* | 582.72* | 586.79* | 598.73* |

* in millions

**Table 3.** Parameter at time α = 0.3

| Mean Squared Error | | β | | | | |
|---|---|---|---|---|---|---|
| | | **0.1** | **0.2** | **0.3** | **0.4** | **0.5** |
| $\gamma$ | 0.1 | 725.35* | 601.28* | 559.82* | 545.32* | 542.73* |
| | 0.2 | 641.53* | 542.14* | 511.10* | 502.28* | 502.98* |
| | 0.3 | 583.91* | 502.29* | 478.67* | 474.46* | 478.55* |
| | 0.4 | 544.75* | 476.60* | 458.54* | 458.09* | 465.30* |
| | 0.5 | 518.60* | 461.38* | 447.79* | 450.46* | 460.42* |
| | 0.6 | 501.76* | 453.96* | 444.28* | 449.65* | 461.94* |
| | 0.7 | 491.74* | 452.50* | 446.47* | 454.21* | 468.36* |
| | 0.8 | 487.00* | 455.78* | 453.27* | 463.10* | 478.59* |
| | 0.9 | 486.66* | 463.02* | 463.92* | 475.55* | 491.85* |

* in millions

**Table 4.** Parameter at time α = 0.4

| Mean Squared Error | | β | | | | |
|---|---|---|---|---|---|---|
| | | **0.1** | **0.2** | **0.3** | **0.4** | **0.5** |
| $\gamma$ | 0.1 | 586.87* | 516.73* | 497.89* | 495.90* | 501.42* |
| | 0.2 | 524.13* | 468.08* | 455.00* | 455.53* | 461.87* |
| | 0.3 | 480.22* | 434.30* | 425.78* | 429.00* | 437.04* |
| | 0.4 | 450.07* | 411.70* | 406.81* | 412.59* | 422.60* |
| | 0.5 | 429.89* | 397.46* | 395.52* | 403.59* | 415.49* |
| | 0.6 | 416.91* | 389.48* | 390.00* | 400.02* | 413.54* |
| | 0.7 | 409.13* | 386.17* | 388.83* | 400.45* | 415.21* |
| | 0.8 | 405.19* | 386.41* | 390.99* | 403.88* | 419.50* |
| | 0.9 | 404.17* | 389.44* | 395.77* | 409.67* | 425.91* |

* in millions

**Table 5.** Parameter at time α = 0.5

| Mean Squarred Error | | β | | | | |
|---|---|---|---|---|---|---|
| | | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 |
| $\gamma$ | 0.1 | 523.21* | 481.08* | 474.72* | 480.41* | 491.61* |
| | 0.2 | 470.91* | 437.38* | 433.85* | 439.90* | 450.09* |
| | 0.3 | 432.71* | 405.59* | 404.65* | 411.70* | 421.93* |
| | 0.4 | 405.30* | 383.03* | 384.38* | 392.75* | 403.62* |
| | 0.5 | 386.09* | 367.58* | 370.92* | 380.72* | 392.54* |
| | 0.6 | 373.01* | 357.55* | 362.63* | 373.80* | 386.70* |
| | 0.7 | 364.47* | 351.63* | 358.22* | 370.65* | 384.65* |
| | 0.8 | 359.28* | 348.80* | 356.73* | 370.29* | 385.37* |
| | 0.9 | 356.56* | 348.33* | 357.48* | 372.08* | 388.27* |

* in millions

In Table 1, the lowest Mean Squarred Equation (MSE) values are found when α = 0.1, β = 0.5, and ϒ = 0.4. In Table 2, the smallest Mean Squarred Equation (MSE) values occur when α = 0.2, β = 0.4, and ϒ = 0.4. In Table 3, the smallest Mean Squarred Equation (MSE) values are achieved at α = 0.3, β = 0.3, and ϒ = 0.4. In Table 4, the lowest Mean Squarred Equation (MSE) values occur when α = 0.4, β = 0.2, and ϒ = 0.4. Meanwhile in Table 5, the smallest Mean Squarred Equation (MSE) values were found when α = 0.5, β = 0.1, and ϒ = 0.4, as shown in Table 6.

**Table 6.** Determining the lowest Mean Squarred Equation (MSE) value in each α table.

| Lowest Mean Squarred Equation (MSE) | $\alpha$ | $\beta$ | $\gamma$ |
|---|---|---|---|
| 803976591.60 | 0.1 | 0.5 | 0.4 |
| 558163839.45 | 0.2 | 0.4 | 0.4 |
| 458540884.90 | 0.3 | 0.4 | 0.4 |
| 411697435.33 | 0.4 | 0.2 | 0.4 |
| 405303661.37 | 0.5 | 0.1 | 0.4 |

To obtain optimal predictions, the error value must be minimized. Therefore, in this study, the Mean Squarred Equation (MSE) value chosen is one that uses the components α = 0.5, β = 0.1, and ϒ = 0.4. So the prediction graph for the next four yearss can be seen in Figure 2.

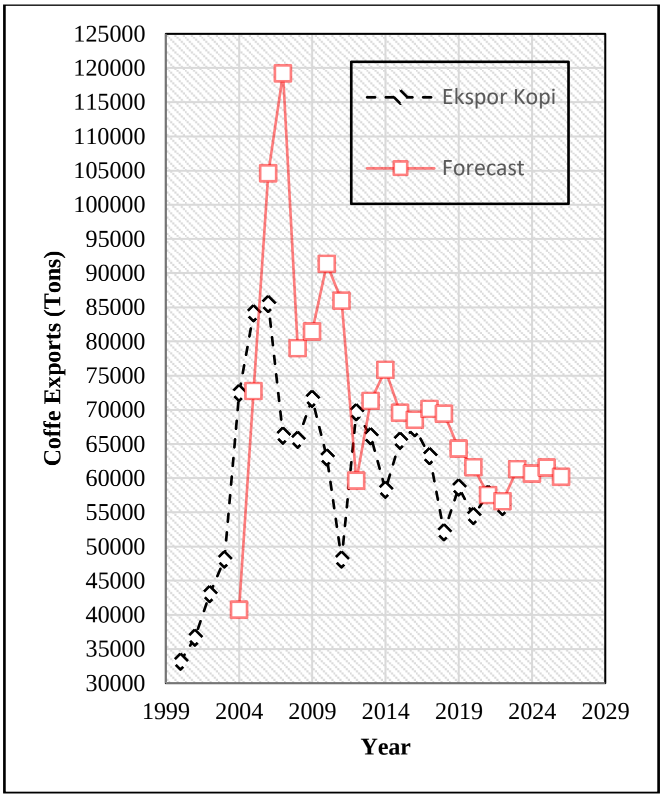


**Figure 2.** Data graphs along with predicted forecasting results.

Forecasting results using the Holt-Winters Exponential method are shown in Table 7.

**Table 7.** Forcasting results

| Period | Year | Forecasting (Tons) |
|---|---|---|
| 1 | 2023 | 61332.69 |
| 2 | 2024 | 60661.50 |
| 3 | 2025 | 61563.27 |
| 4 | 2026 | 60196.50 |

## 4. Conclusion

Research on "Forecasting Coffee Exports to the United States Using the Smoothing Holt-Winters Exponential Method" holds significant urgency in the context of global coffee trade dynamics. As the United States remains one of the largest importers of coffee worldwide, accurate forecasting of coffee exports to this market is crucial for both exporting countries and importing businesses. The Holt-Winters Exponential Method, known for its effectiveness in time series forecasting, presents a promising approach to predict future trends in coffee exports with enhanced precision. By utilizing this method, researchers can provide valuable insights into the expected volume and patterns of coffee exports to the United States, aiding stakeholders in making informed decisions regarding production, marketing, and trade strategies. Additionally, such research contributes to the optimization of supply chain management, risk mitigation, and market competitiveness in the global coffee industry. Given the dynamic nature of coffee markets and the potential impact of various factors such as climate change, economic fluctuations, and consumer preferences, timely and accurate forecasting is indispensable for ensuring the sustainability and resilience of coffee trade relationships between exporting countries and the United States. Therefore, conducting research on this topic is not only academically enriching but also practically imperative for fostering efficient and sustainable coffee trade practices on a global scale.

The results of this research are four periods (year) forecasting using the Holt-Winters Exponential method, with the component selection α = 0.5, β = 0.1, and ϒ = 0.4. This selection is based on the smallest Mean Squarred Equation (MSE) value. Predictions show that in 2023, Indonesia is expected to export 61,332.60 tonnes of coffee to the United States, in 2024 it is estimated at 60,661.50 tonnes, in 2025 it is estimated at 61,563.27 tonnes, and in 2026 it is estimated at 60,196.50 tonnes.

Based on the outlined methodological approach for forecasting coffee exports to the United States using the Holt-Winters Exponential Smoothing method, several suggestions can be made to enhance the research:

1. Incorporate Multiple Forecasting Methods: While the Holt-Winters Exponential Smoothing method is effective, it would be beneficial to compare its performance with other forecasting techniques such as ARIMA (Auto Regressive Integrated Moving Average) or machine learning algorithms like neural networks. This comparative analysis can provide a broader understanding of the strengths and weaknesses of each method in forecasting coffee exports.
2. Long-Term Forecasting: While short-term forecasting is essential for immediate decision-making, long-term forecasting can provide valuable insights for strategic planning and policy formulation. Researchers could extend the forecasting horizon to predict coffee export trends over several years or decades, considering factors like emerging market trends and technological advancements in the coffee industry.

## REFERENCES


Aini, N. N., Iriany, A., Nugroho, W. H., & Wibowo, F. L. (2022). Comparison of Adaptive Holt-Winters Exponential Smoothing and Recurrent Neural Network Model for Forecasting Rainfall in Malang City. *ComTech: Computer, Mathematics and Engineering Applications*, *13*(2), 87–96.

Andriani, N., Wahyuningsih, S., & Siringoringo, M. (2022). Application of Double Exponential Smoothing Holt and Triple Exponential Smoothing Holt-Winter with Golden Section Optimization to Forecast Export Value of East Borneo Province. *Jurnal Matematika, Statistika Dan Komputasi*, *18*(3), 475–483.

Atoyebi, S. B., Olayiwola, M. F., Oladapo, J. O., & Oladapo, D. I. (2023). Forecasting Currency in Circulation in Nigeria Using Holt-Winters Exponential Smoothing Method. *South Asian Journal of Social Studies and Economics*, *20*(1), 25–41.

Caspah, L. (2017). Modelling and Forecasting Inflation Rate in Kenya Using SARIMA and Holt-Winters Triple Exponential Smoothing. *American Journal of Theoretical and Applied Statistics*, *6*(3), 161.

Dewi, N. P., & Listiowarni, I. (2020). Implementasi Holt-Winters Exponential Smoothing untuk Peramalan Harga Bahan Pangan di Kabupaten Pamekasan. *Digital ZOne: Jurnal Teknologi Informasi & Komunikasi*, *11*(2), 219–231.

Efrilia, I. (2021). Comparison Of ARIMA And Exponential Smoothing Holt-Winters Methods For Forecasting CPI In The Tegal City, Central Java. *Jurnal Ekonomi Pembangunan*, *19*(02), 97–106.

Febriyanti, A. N., & Rifai, N. A. K. (2022). Metode Triple Exponential Smoothing Holt-Winters untuk Peramalan Jumlah Penumpang Kereta Api di Pulau Jawa. *Bandung Conference Series: Statistics*, *2*(2), 152–158.

Handika, I. P. S., & Satwika, I. K. S. (2023). Enhancing Sales Forecasting Accuracy Through Optimized Holt-Winters Exponential Smoothing with Modified Improved Particle Swarm Optimization. *Jurnal Nasional Pendidikan Teknik Informatika (JANAPATI)*, *12*(2), 203–212.

Hariri, F. R., & Prakasa, J. E. W. (2023). Chicken Menu Sales Forecasting System Using Multiplicative Holt-Winters Triple Exponential Smoothing. *MATICS: Jurnal Ilmu Komputer Dan Teknologi Informasi* , *15*(1), 8–14.

Mendila, S. A., Utami, I. T., & Kartikasari, P. (2023). Peramalan Jumlah Penumpang Kereta Api di Pulau Jawa Menggunakan Metode Holt-Winters Exponential Smoothing dan Fuzzy Time Series Markov Chain. *Jurnal Gaussian*, *12*(1), 104–115.

Nurhamidah, Nusyirwan, & Faisol, A. (2020). Forcasting Seasonal Time Series Data Using The Holt-Winters Exponential Smoothing Method of Additive Models. *Jurnal Matematika Integratif*, *16*(2), 151.

Pleños, M. C. F. (2022). Time Series Forecasting Using Holt-Winters Exponential Smoothing: Application to Abaca Fiber Data. *Zeszyty Naukowe SGGW w Warszawie - Problemy Rolnictwa Światowego*, *22*(2), 17–29.

Rahman, D., SUmarjaya, I. W., & Sukarsa, I. K. G. (2018). Perbandingan Peramalan Hasil Produksi Ikan Menggunakan Metode Permulusan Ekspnensial Holt-Winters dan ARIMA. *E-Jurnal Matematika*, *7*(4), 371.

Siregar, Y. J., Hartono, R., & Hardana, A. E. (2021). Peramalan Harga Cabai Rawit di Kota Malang dengan Metode Holt-Winters Exponential Smoohting. *Agricore: Jurnal Agribisnis Dan Sosial Ekonomi Pertanian*, *6*(2), 99–110.

Utami, R., & Atmojo, S. (2017). Perbandingan Metode Holt Exponential Smoothing dan Winter Exponential Smoothing Untuk Peramalan Penjualan Souvenir. *Jurnal Ilmiah Teknologi Informasi Asia*, *11*(2).