




Fuzzy Time Series and Double Exponential Smoothing in Farmer's Terms of Trade Forecasting of Bali Province

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Abstract. The Farmer's Terms of Trade (FTT) plays a vital role in supporting key sectors of the Indonesian economy and contributes significantly to improving household incomes. This study utilizes monthly FTT data from Bali, spanning from January 2017 to June 2021, sourced from the official website of the Central Statistics Agency (BPS). The research aims to compare the forecasting accuracy of a modified Algorithm based on the Fuzzy Time Series method with that of the Double Exponential Smoothing (DES) in predicting the FTT in Bali. The results of the accuracy assessment indicate that the Double Exponential Smoothing delivers superior and more accurate forecasting performance. This is demonstrated by its lower Mean Squared Error (MSE) and Mean Absolute Percentage Error (MAPE) compared to the modified algorithm based on Fuzzy Time Series. Specifically, with $\alpha = 0.9$ and $\gamma = 0.03$, the DES method achieves an MSE of 1.73 and the lowest MAPE value of 0.61, confirming its effectiveness in modeling the FTT data.

Keywords: Bali, Double Exponential Smoothing, Farmer's Terms of Trade, Forecasting, Fuzzy Time Series.

1 Introduction

The agricultural sector is one of the supporting pillars of Indonesia's economy. It plays a significant role in increasing community income, absorbing labor, generating foreign exchange through exports, and creating conducive conditions for development while maintaining synergistic relationships with other sectors. The agricultural sector also significantly impacts poverty issues, as agriculture is a primary source of livelihood. The larger the agricultural sector, the lower the poverty rate. One indicator that reflects farmers' welfare is the Farmers' Terms of Trade. FTT is the ratio between the Price Index received by farmers (I_t) and the Price Index paid by farmers (I_b). FTT data is obtained from the Bali Provincial Statistics Agency (BPS) and covers the period from January 2017 to June 2021. This study will compare the accuracy levels of the Fuzzy Time Series method with the application of the modified algorithm proposed by Jasim et al (2012) and Double Exponential Smoothing in forecasting the Farmer's Terms of Trade in Bali Province. The aim is to provide information that can serve as a reference

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for future forecasting case studies conducted by the authors and to potentially form policies and guidelines to minimize decreases in the Farmer's Terms of Trade.

Several previous studies are referenced in this report. These references encompass forecasting theories, forecasting methods, and methods for testing prediction accuracy. One such study involves applying the modified algorithm based on the Fuzzy Time Series method to predict the Farmer's Terms of Trade by comparing the accuracy levels of different methods and selecting the best one for FTT data prediction. The results show that predictions using the modified algorithm based on the Fuzzy Time Series method yield better accuracy, with an MSE value of 0.01 and a MAPE value of 0.08 (Meirissa, 2016). Another study compared forecasts of the Rupiah's Exchange Rate against the US Dollar to determine which method was more accurate between the Fuzzy Time Series Hsu Method and Double Exponential Smoothing. The results showed that the Fuzzy Time Series Hsu Method had a smaller forecasting error, at 0.6% (Anggraeni, 2016). The Fuzzy Time Series method was also used to predict the exchange rate of the Rupiah against the US Dollar by comparing the Fuzzy Time Series method proposed by Ruey Chyn Tsaor and the novel algorithm proposed by Jasim. The results showed that the modified algorithm had the smallest MAPE value of 0.003316 (0.3316%) (Riyadli, 2015).

Additionally, forecasting comparisons have been used to determine the most accurate method for predicting the Farmer's Terms of Trade in Indonesia. Calculations of accuracy using MAPE and MSE revealed that the Fuzzy Time Series Cheng method performed better than the Fuzzy Time Series Markov Chain method in forecasting FTT (Mustika, 2021).

2 Methodology

2.1 Fuzzy Set

A fuzzy set is a group that represents a specific condition within a fuzzy variable. A fuzzy set has a universal set, which is the entire range of values obtained to operate within which the fuzzy variable operates. Membership values in a fuzzy set fall within the range of 0 to 1. A value of 0 indicates false, and a value of 1 indicates true, among other possibilities. Fuzzy sets explain each value based on opinions or decisions (Meirissa, 2016).

2.2 Fuzzy Time Series

Fuzzy sets represent the fuzzy time series method as numbers or real values over a defined universal set (Nugroho, 2016). Fuzzy sets can be interpreted as classes with imprecise numerical boundaries.

2.3 Modified Algorithm based on the Fuzzy Time Series

Jasim et al (2012) propose a new method to forecast enrollments based on fuzzy time series. This novel algorithm, based on the Fuzzy Time Series, presents better forecasting results and can achieve a higher forecasting accuracy rate for forecasting enrollments than the existing methods (Jasim et al., 2012).

2.4 Exponential Smoothing

Exponential smoothing is a method that applies exponentially decreasing weights to older observation values. The exponential smoothing method consists of single, double, and more complex methods. In this method, forecasting is performed by repeatedly calculating using new data with similar characteristics, where the new values are given relatively larger weights compared to older observations (Pujiati, Yuniarti, & Goejantoro, 2016).

2.5 Double Exponential Smoothing (Brown Method)

This method is used when data shows a trend. A trend is a smoothed estimate of the average growth at the end of each period. Double Exponential Smoothing can be calculated using three data values and one value for alpha (Pujiati, Yuniarti, & Goejantoro, 2016).

2.6 Accuracy Testing

To measure the accuracy of forecasting, a method is used to calculate it, with the forecasting technique that produces the smallest error being the most suitable to use (Faroh, 2016). Forecast results are not always accurate and often differ from actual conditions (actual data). There are several methods to measure the error level in forecasting, including (Pramita & Tanuwijaya, 2010):

Mean Square Error (MSE). The Mean Square Error (MSE) method is a forecasting technique that calculates the error for each data point (the difference between the actual data and the forecast data). MSE has criteria indicating that the smaller the MSE value, the better the accuracy. MSE represents the average squared error for each data point, with the formula as equation (1):

$$MSE = \frac{1}{n} \sum_{t=1}^n (Y(t) - F(t))^2 \quad (1)$$

MSE has a criterion indicating that the smaller the MSE value, the better the accuracy. The MSE value criteria are shown in Table 1 (Hudiyanti et al., 2019).

Mean Absolute Percentage Error (MAPE). This is the average absolute percentage error, calculated from the absolute error values for each period, divided by the actual

data for that period, and then averaged. MAPE is calculated using the formula (2) (Meirissa, 2016):

$$MAPE = \frac{1}{n} \sum_{t=1}^n \frac{|Y(t)-F(t)|}{Y(t)} \times 100\% \quad (2)$$

In the MAPE method, there is a criterion indicating that the smaller the MAPE value, the better the accuracy. The MAPE value criteria are shown in Table 2 (Hudiyanti et al., 2019).

Table 1. MSE Criteria

MAPE	Criteria
< 10	Very Good
10 - 20	Good
20 - 50	Fair
> 50	Poor

Table 2. MAPE Criteria

MAPE	Criteria
< 10	Very Good
10 - 20	Good
20 - 50	Fair
> 50	Poor

2.7 Farmer's Terms of Trade

Farmer's Terms of Trade refer to the ratio between the price index received by farmers (It) and the price index of farmers (Ib), expressed as a percentage. The price index received by the farmers (It) reflects changes in the prices of agricultural products at the producer level. In contrast, the price index paid by farmers (Ib) indicates changes in the prices of goods and services required for household consumption and other farming-related needs. FTT also serves as an important indicator for assessing farmers' purchasing power and evaluating their level of welfare. A higher FTT index generally reflects a stronger purchasing power and a relatively better standard of living for farmers (BPS Bali, 2021).

3 Result and Discussion

3.1 Data Analysis

In this study, the research material required is the data on the Farmer's Terms of Trade, which were obtained from the official website of the Bali Provincial Statistics Office (Badan Pusat Statistik Provinsi Bali) at bali.bps.go.id. The author collected monthly time series data on the Farmer's Terms of Trade in Bali Province, covering the period

from January 2017 to June 2021. Based on Table 2, it shows that farmers experienced a decline or deficit. The increase in agricultural product prices was relatively smaller than the increase in the prices of consumer goods. As a result, farmers’ incomes decreased and became lower than their expenditures. In time series data, the long-term pattern of increases and decreases is referred to as a trend. The trend analysis, conducted using Minitab software, is presented in Figure 1, which illustrates the FTT data exhibiting a discernible trend pattern.

Table 3. Farmer’s Terms of Trade Data in Bali, January 2017-June 2021

Period	Data	Period	Data	Period	Data
Jan-17	106.25	Jul-18	103.40	Jan-20	96.27
Feb-17	105.79	Agt-18	103.54	Feb-20	96.63
Mar-17	104.72	Sep-18	103.28	Mar-20	97.10
Apr-17	104.98	Oct-18	103.70	Apr-20	94.81
May-17	104.57	Nov-18	103.15	May-20	93.54
Jun-17	104.49	Dec-18	103.87	Jun-20	93.53
Jul-17	104.14	Jan-19	103.65	Jul-20	93.92
Agt-17	103.94	Feb-19	103.98	Agt-20	93.34
Sep-17	104.45	Mar-19	104.13	Sep-20	93.16
Oct-17	104.49	Apr-19	103.45	Oct-20	92.83
Nov-17	104.51	May-19	103.37	Nov-20	92.61
Dec-17	103.93	Jun-19	103.58	Dec-20	93.56
Jan-18	103.48	Jul-19	104.89	Jan-21	93.09
Feb-18	103.88	Agt-19	104.65	Feb-21	92.46
Mar-18	103.50	Sep-19	104.14	Mar-21	91.46
Apr-18	103.18	Oct-19	103.66	Apr-21	92.12
May-18	103.23	Nov-19	104.35	May-21	91.93
Jun-18	103.54	Dec-19	104.93	Jun-21	92.38

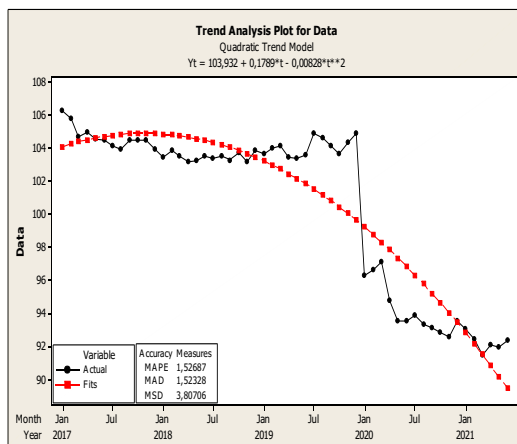


Figure 1. Trend Analysis Graph of the Farmer’s Terms of Trade

3.2 Result

Calculation of The Jasim Algorithm Based on The Fuzzy Time Series Method.

Step 1. Determining the Universe of Discourse U. Based on Table 2, the lowest FTT value (D_{min}) was 91.46 in March, and the highest (D_{max}) was 106.25 in January 2017. The parameters D1 and D2 were set at 0 and 0, respectively, to define the universe of discourse. Using equation (2), the universe of discourse U is determined as $= [91,46, 106,45]$.

Step 2. Determining the Interval Length (I) using the Average-Based Method. The result was rounded according to the defined base, yielding an interval length of 0.3.

Step 3. Determining the Number of Intervals. Based on Equation (3), the interval (m) was calculated as 49.96666667. This value was rounded to 50 intervals, with each interval having a length of 0.3.

Step 4. Fuzzy sets were defined for the entire universe of discourse U using 50 intervals to form the fuzzy sets A_i . The fuzzification process of the historical FTT data followed this.

Step 5. Determining the Fuzzy Logical Relationship (FLR). Based on Table 5, the Fuzzy Logical Relationships (FLR) can be established by linking the data from the previous month to the data of the following month according to the rule $A_i \rightarrow A_j$. This process identifies the transition between fuzzy sets over time.

Step 6. Determining Fuzzy Logical Relationship Groups (FLRG). Based on Table 6, the Fuzzy Logical Relationship Groups (FLRG) for the entire FTT dataset can be constructed.

Step 7. Forecasting Result. Based on the rules and procedures of the modified algorithm using the Fuzzy Time Series method, the forecasting results for the subsequent data points are presented in Table 4.

Table 4. Forecasting Results Using the Modified Algorithm Based on the Fuzzy Time Series

Period	Data	Forecasting Result	Period	Data	Forecasting Result
Jan-17	106.25	-	Apr-19	103.45	103.91
Feb-17	105.79	105.71	May-19	103.37	103.46
....
Feb-19	103.98	103.85	May-21	91.93	91.91
Mar-19	104.13	104.11	Jun-21	92.38	92.51

Calculation Using The Double Exponential Smoothing. Based on the trend analysis, the forecast values using the Double Exponential Smoothing method were calculated with the assistance of Minitab software, using smoothing parameters $\alpha = 0.9$ and $\gamma = 0.03$. The forecasting results obtained through the Double Exponential Smoothing method are presented in Table 5.

Table 5. Forecasting Results Using the Double Exponential Smoothing Method

Period	Data	Forecasting Result	Period	Data	Forecasting Result
Jan-17	106.25	106.505	Apr-19	103.45	104.075
Feb-17	105.79	105.437	May-19	103.37	103.383
....
Feb-19	103.98	103.579	May-21	91.93	91.827
Mar-19	104.13	103.916	Jun-21	92.38	91.649

3.3 Discussion

Accuracy Testing of The Jasim Algorithm Based on the Fuzzy Time Series. The accuracy of the forecasting results was evaluated using the Mean Squared Error (MSE) criterion, as defined by equation (12), and the Mean Absolute Percentage Error (MAPE), as defined by equation (13). The accuracy testing results for the method are presented in Table 6.

Table 6. Accuracy Testing Results of the Modified Algorithm Based on the Fuzzy Time Series

Period	Data	Modified fuzzy forecasting	MSE	MAPE
Jan-17	106.25	-	-	-
Feb-17	105.79	106.25	0.2116	0.4348
....
Mei-21	91.93	92.12	0.0361	0.2067
Jun-21	92.38	91.93	0.2025	0.4871
Σ			1.7739	0.6269

Accuracy Evaluation of The Double Exponential Smoothing Method. The accuracy of the Double Exponential Smoothing method was evaluated using the Mean Squared Error (MSE), as defined by equation (12), and the Mean Absolute Percentage Error (MAPE), as defined by equation (13). The accuracy testing results for this method are presented in Table 7.

Table 7. Accuracy Evaluation of the Double Exponential Smoothing Method

Period	Data	Double exponential smoothing forecasting	MSE	MAPE
Jan-17	106.25	106.505	0.06484	0.23965
Feb-17	105.79	105.437	0.12463	0.33371
....
Mei-21	91.93	91.827	0.01066	0.11230
Jun-21	92.38	91.649	0.53434	0.79128
Σ			1.72598	0.61170

Result of Accuracy Testing. Based on the accuracy calculation result, the forecasting accuracy for the Farmer's Terms of Trade in Bali Province is presented in Table 8. It can be concluded that both methods are suitable for forecasting the Farmers' Terms of Trade, as indicated by their MSE and MAPE values, which are below 10. However, based on the comparison of the MSE and MAPE values obtained from each method, the Double Exponential Smoothing method produced lower MSE and MAPE values.

Table 8. Accuracy Testing Result

Method	MSE	MAPE
Jasim et al Algorithm Based on Fuzzy Time Series	1.77	0.63
Double Exponential Smoothing	1.73	0.61

Therefore, it can be concluded that the Double Exponential Smoothing method demonstrates better performance and higher accuracy in forecasting the Farmers' Terms of Trade data in Bali Province, as it yields very good accuracy (MSE and MAPE values below 10) and performs better than the modified algorithm based on the Fuzzy Time Series method.

Comparison of Forecasting Results Between The Fuzzy Time Series and The Double Exponential Smoothing. The comparison of forecasting results is presented in Table 9, while the graphical comparison of the forecasting results shown in Table 9 is shown in Figure 2.

Table 9. Comparison of Forecasting Results Between the Fuzzy Time Series and the Double Exponential Smoothing

Period	Data	Fuzzy time series algorithm	Double exponential smoothing
Jan-17	106.25	-	106.50
Feb-17	105.79	106.25	105.44
....
May-21	91.93	92.12	91.83
Jun-21	92.38	91.93	91.65

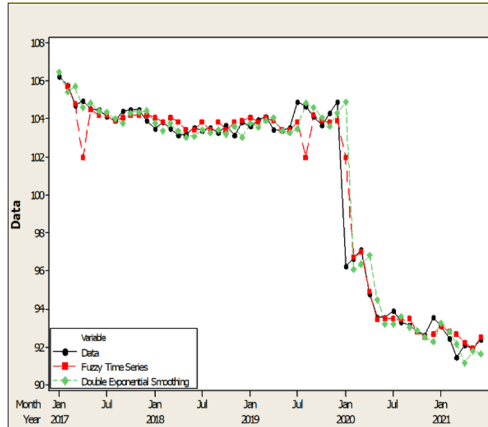


Figure 2. Forecasting Result Comparison Chart

Based on Figure 2, the forecasting results using the Double Exponential Smoothing method exhibit a pattern that closely follows the actual Farmer's Terms of Trade data. This method also demonstrates higher accuracy compared to the Fuzzy Time Series method. The relatively small differences in the forecasting results may be attributed to the differences in the calculation processes of the two methods.

4 Conclusion

Based on the analysis and discussion presented, the following conclusions can be drawn. Based on the comparison of forecasting results, the Double Exponential Smoothing method is more suitable for modeling the Farmer's Terms of Trade data, which exhibit long-term upward or downward trends. The application of the Double Exponential Smoothing method to the Farmer's Terms of Trade data in Bali Province produces forecast patterns that closely follow or approximate the actual Farmer's Terms of Trade data. The comparison results show that the Double Exponential Smoothing method, with optimal parameters $\alpha=0.9$ and $\gamma=0.03$, provides the best forecasting performance for the Farmer's Terms of Trade in Bali Province for the period from January 2017 to June 2021. This method resulted in an MSE of 1.73 and a MAPE of 0.61. In comparison, the modified Algorithm based on the Fuzzy Time Series method produced an MSE of 1.77 and a MAPE of 0.63. Double Exponential Smoothing is proven to be more effective and accurate in forecasting the Farmer's Terms of Trade data in Bali Province. This is indicated by its lower MSE and MAPE values compared to those of the modified algorithm based on the Fuzzy Time Series method.

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