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Inflation Forecasting in Indonesia Using Lee's Fuzzy Time Series Method

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Abstract

Inflation is an important economic indicator, the rate of growth is should be low and stable. Unstable inflation will complicate people's decisions to consume, invest and produce which in turn will reduce economic growth. One of the effects of this inflation is slow economic growth. For this reason, the government needs to consider policies that can influence it. Bank Indonesia one of the policies to control inflation is monetary. Forecasting methods are used to help facilitate future planning and can be used as guidelines for decision making that can improve economic performance. Forecasting used is fuzzy time series Lee. The data used is monthly inflation data in Indonesia for the period January 2017-May 2022. The error rate used is MAPE which produces a very good MAPE value of 8,16%. Forecasting results for the next period, June 2022, amounted to 3,66%.

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1. Introduction

Indonesia is a developing country that generally has economic problems, one of which is inflation. Inflation can be caused by various factors, such as excessive money circulation and an imbalance between the demand and supply of a good or service (Ramdhani, 2024). Rising inflation can cause the prices of goods and services in the country to rise. The increase in the price of goods and services will cause a decrease in the value of the currency so that it can reduce people's purchasing power (Linggi *et al*., 2024). This can result in slow economic growth. Empirical experience shows that unstable inflation will complicate people's decisions in consumption, investment and production, which in turn will reduce economic growth (Hernaningsih, 2015).

The relationship between economic growth and inflation in Indonesia from 2022 to 2024 shows a complex interaction. In 2022, strong economic growth increases inflation. A decline in growth in 2023 helped ease inflation, although tight monetary policy also impacted investment. The 2024 projection shows moderate growth of around 5,0% with inflation estimated at 3,5% to 4,0%, supporting economic stability (Putri, 2024). This shows that inflation in Indonesia has a close relationship with economic development, so the government needs to consider policies that can affect it. One way to control inflation is by forecasting. Forecasting is a step to be able to simulate future data by analyzing past data, based on these past data, company executives can make strategic steps to achieve previously defined margins (Utami & Atmojo, 2017).

Fuzzy Time Series is one of the soft computing methods that has been used and applied in the analysis of time series data. The main purpose of Fuzzy Time Series is to predict time series data that can be widely used on any real time data (Mustawinar *et al*., 2024). The method uses fuzzy logic in time series forecasting problems that are able to provide explanations for data presented in linguistic values which are group names in the form of words (Virgianti *et al*., 2021). The advantage of this method is that it can be widely used on real time data (Febrianti *et al*., 2020). In addition, Fuzzy Time Series also does not require a large amount of historical data and does not require assumptions to be met (Ekananta *et al*., 2018).

There are three categories of Fuzzy Time Series, namely Chen, Cheng, and Lee Fuzzy Time Series (Sofiyanti *et al*., 2024). The Chen and Cheng models are almost the same but there is a slight difference in the Fuzzy Logical Relationship Group (FLRG) formation step by including all relationships and giving weights based on the same order and recurrence (Mahendra *et al*., 2024). Meanwhile, Lee's model is a development of Chen and Cheng's model. This model has steps for forecasting that are almost the same as other Fuzzy Time Series. Fuzzy Time Series Lee pays attention to recurrence or keeps calculating the same FLR (Muhammad *et al.,* 2021). Lee's Fuzzy Time Series is used for short-term forecasting with stationary or non-stationary data patterns (Vivianti *et al.,* 2024).

Previous research conducted by Handayani & Anggriani (2015) is a comparison of fuzzy time series Chen model and Lee model with gold price data. The results showed that data prediction using Fuzzy Time Series with average-based interval determination had an error with the Chen AFER model of 0,010% and MSE 218,577, the Lee model averaged AFER 0,0013% and MSE 212,092. From the test results that have been carried out, it can be proven that the Fuzzy Time Series method using the Lee model produces a lower error rate than the Chen model.

In this research, Lee's Fuzzy Time Series method will be used by Handayani & Anggriani (2015) to predict inflation in Indonesia based on historical inflation data from January 2017 to May 2022. Error calculation is done by calculating the Mean Absolute Percentage Error (MAPE) to determine the average of the overall percentage error between actual data and forecasting data. Lee's Fuzzy Time Series is then applied to predict inflation in the following month.

2. Methods

The research used secondary data obtained from the Bank Indonesia website, namely Inflation data in Indonesia for the period January 2017-May 2022. The application of Lee's Fuzzy Time Series method is as follows:

a. Formation of the universe of talks (U), using inflation data in Indonesia for the period January 2017 to May 2022 by determining the minimum data (D_{min}) and maximum data (D_{max}).
b. Determining many intervals, calculating the length of the interval then dividing the universe of speech into several parts and then finding the middle value of each interval with the equation.
c. Determining the fuzzy set formed through the membership degree then determining the fuzzy set using the equation.
d. Performing fuzzification on inflation data in Indonesia, fuzzification is done by looking at the results of the interval.
e. Determining Fuzzy Logic Relationship (FLR).
   FLR is an activity carried out to connect the relationship between linguistic values that have been determined based on the results of fuzzification.
f. Determining the Fuzzy Logic Relationship Group (FLRG) by classifying the Fuzzy Logic Relationship (FLR) into groups. For example, $A_1 \rightarrow A_1, A_1 \rightarrow A_1, A_1 \rightarrow A_2$ will produce $A_1 \rightarrow A_1, A_1, A_2$.
g. Performing the defuzzification process, at this stage, the fuzzy output will be converted into a firm value to produce a forecasting value.
h. Calculate the forecasting error rate, calculate the error rate of each forecasting result using MAPE.
i. Calculating forecasts for the next period forecasting for the next period is seen from the current state and the results of the defuzzification calculation.

3. Results and Discussions

3.1. Descriptive Analysis

The inflation data for Indonesia from January to May 2022 reveals an average inflation rate of 2,73%. Over the observed period, the highest inflation rate was recorded in June 2017 at 4,37%, while the lowest occurred in August 2020 at 1,32%. As depicted in Figure 1, the overall inflation trend from January 2017 to May 2022 indicates a gradual decline. Notable fluctuations include the most significant increase in inflation observed between March 2022 and April 2022, where it rose by 0,83%, and the steepest decrease occurring between June 2017 and July 2017, with a drop of 0,49%. These movements highlight key points of volatility within the inflationary trends during this period.

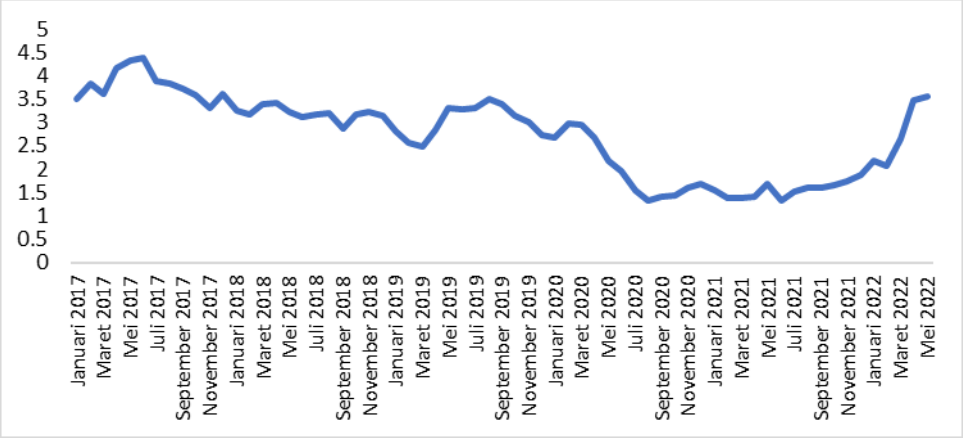

Figure 1 Graph of inflation data in Indonesia

3.2. Lee's Fuzzy Time Series

Forming the universe of speech U

The universe of speech $U = [D_{min}\ ;\ D_{max}]$, the minimum data is 1,32 in August 2020 and the maximum data is 4,37 in June 2017, so that $U = [1{,}32\ ;\ 4{,}37]$ is obtained.

Determining intervals and centre values

1. Determining the number of intervals
   $K = 1 + 3{,}3\ log\ n$, where n is the amount of data.
   $= 1 + 3{,}3\log(65)$
   $= 6{,}98$ rounded up to 7
2. Determining the length of the interval
   $l = \frac{D_{max} - D_{min}}{n}$
   $= \frac{(4{,}37 - 1{,}32)}{7}$
   $= 0{,}44$
3. From the previous calculation, the number of intervals is 7 and the interval length is $0{,}44$, so the data is divided into 7 according to the number of intervals so that the upper and lower limits are obtained as follows:
   $U_1 = [1{,}32\ ;\ 1{,}76]$
   $U_2 = [1{,}76\ ;\ 2{,}20]$
   $U_3 = [2{,}20\ ;\ 2{,}63]$
   $U_4 = [2{,}63\ ;\ 3{,}07]$
   $U_5 = [3{,}07\ ;\ 3{,}50]$
   $U_6 = [3{,}50\ ;\ 3{,}94]$
   $U_7 = [3{,}94\ ;\ 4{,}37]$
4. Find the centre value

Table 1 Center value

Interval Class	Center Value
A_1	1,54
A_2	1,98
A_3	2,41
A_4	2,85
A_5	3,29
A_6	3,72
A_7	4,16

Fuzzy Set

$$A_1 = {}^{1}/_{u_1} + {}^{0,5}/_{u_2} + {}^{0}/_{u_3} + {}^{0}/_{u_4} + {}^{0}/_{u_5} + {}^{0}/_{u_6} + {}^{0}/_{u_7}$$
$$A_2 = {}^{0,5}/_{u_1} + {}^{1}/_{u_2} + {}^{0,5}/_{u_3} + {}^{0}/_{u_4} + {}^{0}/_{u_5} + {}^{0}/_{u_6} + {}^{0}/_{u_7}$$
$$A_3 = {}^{0}/_{u_1} + {}^{0,5}/_{u_2} + {}^{1}/_{u_3} + {}^{0,5}/_{u_4} + {}^{0}/_{u_5} + {}^{0}/_{u_6} + {}^{0}/_{u_7}$$
$$A_4 = {}^{0}/_{u_1} + {}^{0}/_{u_2} + {}^{0,5}/_{u_3} + {}^{1}/_{u_4} + {}^{0,5}/_{u_5} + {}^{0}/_{u_6} + {}^{0}/_{u_7}$$
$$A_5 = {}^{0}/_{u_1} + {}^{0}/_{u_2} + {}^{0}/_{u_3} + {}^{0,5}/_{u_4} + {}^{1}/_{u_5} + {}^{0,5}/_{u_6} + {}^{0}/_{u_7}$$
$$A_6 = {}^{0}/_{u_1} + {}^{0}/_{u_2} + {}^{0}/_{u_3} + {}^{0}/_{u_4} + {}^{0,5}/_{u_5} + {}^{1}/_{u_6} + {}^{0,5}/_{u_7}$$
$$A_7 = {}^{0}/_{u_1} + {}^{0}/_{u_2} + {}^{0}/_{u_3} + {}^{0}/_{u_4} + {}^{0}/_{u_5} + {}^{0,5}/_{u_6} + {}^{1}/_{u_7}$$

Fuzzification

Tabel 2 Fuzzification

Period	Inflation	Fuzzification
January 2017	3,49	A_5
February 2017	3,83	A_6
March 2017	3,61	A_6
April 2017	4,17	A_7
May 2017	4,33	A_7
…	…	…
January 2022	2,18	A_2
February 2022	2,06	A_2
March 2022	2,64	A_4
April 2022	3,47	A_5
May 2022	3,55	A_6

The fuzzification result of inflation data in Indonesia is obtained. For example, January 2017 with data 3,49. by looking at the results in Table 1, the data falls into the interval category $[3{,}07;\ 3{,}50]$ so that the fuzzification results are included in A_5.

Fuzzy logical relationship

Fuzzy logical relationship (FLR) is done to link each data sequence to the next data relation.

Table 3 FLR

Period	Inflation	FLR		
January 2017	3,49		→	A_5
February 2017	3,83	A_5	→	A_6
March 2017	3,61	A_6	→	A_6
April 2017	4,17	A_6	→	A_7
May 2017	4,33	A_7	→	A_7
…	…	…	…	…
…	…	…	…	…
January 2022	2,18	A_2	→	A_2
February 2022	2,06	A_2	→	A_2
March 2022	2,64	A_2	→	A_4
April 2022	3,47	A_4	→	A_5
May 2022	3,55	A_5	→	A_6

Fuzzy logical relationship group

Fuzzy logical relationship group (FLRG) which is a grouping of each state transfer, namely current state and next state.

Table 4 FLRG

Current state	Next State
A_1	A_1, A_1, A_1, A_1, A_1 A_1, A_1, A_1, A_1, A_1 A_1, A_1, A_1, A_1, A_1 A_1, A_2
A_2	A_1, A_2, A_2, A_2, A_4
A_3	A_3, A_4
A_4	A_2, A_3 A_4, A_4, A_4, A_4, A_4 A_5, A_5, A_5
A_5	A_4, A_4 A_5, A_5, A_5, A_5, A_5 A_5, A_5, A_5, A_5, A_5 A_5, A_5, A_5, A_5 A_6, A_6, A_6
A_6	A_5, A_5 A_6, A_6, A_6, A_6, A_7
A_7	A_6, A_7, A_7

Defuzzification

At this stage, the fuzzy output will be converted into a firm value to produce a forecasting value.

Tabel 5 Defuzzification

Current state	Next State	Calculations	Forecasting Value
A_1	A_1, A_1, A_1, A_1, A_1 A_1, A_1, A_1, A_1, A_1 A_1, A_1, A_1, A_1, A_1 A_1, A_2	$\frac{16\,(1{,}54)\ +\ 1\,(1{,}98)}{16\ +\ 1}$	1,56
A_2	A_1, A_2, A_2, A_2, A_4	$\frac{1\,(1{,}54)\ +\ 3\,(1{,}98)\ +\ 1\,(2{,}85)}{1\ +\ 3\ +\ 1}$	2,06
A_3	A_3, A_4	$\frac{1\ +\ (2{,}41)\ +\ 1\,(2{,}85)}{1\ +\ 1}$	2,63
A_4	A_2, A_3 A_4, A_4, A_4, A_4, A_4 A_5, A_5, A_5	$\frac{1\,(1{,}98)\ +\ 1\,(2{,}41)\ +\ 5\,(2{,}85)\ +\ 3\,(3{,}29)}{1\ +\ 1\ +\ 5\ +\ 3}$	2,85
A_5	A_4, A_4 A_5, A_5, A_5, A_5, A_5 A_5, A_5, A_5, A_5, A_5 A_5, A_5, A_5, A_5 A_6, A_6, A_6	$\frac{2\,(2{,}85)\ +\ 14\,(3{,}29)\ +\ 3\,(3{,}72)}{2\ +\ 14\ +\ 3}$	3,14
A_6	A_5, A_5 $A_6, A_6, A_6\ A_6, A_7$	$\frac{2\,(3{,}29)\ +\ 4\,(3{,}72)\ +\ 1\,(4{,}16)}{2\ +\ 4\ +\ 1}$	3,66
A_7	A_6, A_7, A_7	$\frac{1\,(3{,}72)\ +\ 2\,(4{,}16)}{1\ +\ 2}$	4,01

The results of this defuzzification can be known for the results of forecasting Inflation data in Indonesia. After the calculation of the forecasting results has been obtained in the previous step based on Table 5, the forecasting results are known as follows:

Table 6 Forecastig value

Period	Inflation	Fuzzification	Current State	Forecast
January 2017	3,49	A_5		
February 2017	3,83	A_6	A_5	3,14
March 2017	3,61	A_6	A_6	3,66
April 2017	4,17	A_7	A_6	3,66
May 2017	4,33	A_7	A_7	4,01
…	…	…	…	…
…	…	…	…	…
January 2022	2,18	A_2	A_2	2,06
February 2022	2,06	A_2	A_2	2,06
March 2022	2,64	A_4	A_2	2,06
April 2022	3,47	A_5	A_4	2,85
May 2022	3,55	A_6	A_5	3,14

Forecasting error rate

Inflation data in Indonesia from January 2017 to May 2022 has a MAPE value of 8,16%, which means that the level of forecasting error in Lee's Fuzzy Time Series method in forecasting inflation in Indonesia has a very good error rate because the MAPE value is $< 10\%$.

Next period forecasting

Based on historical inflation data from January 2017 to May 2022, inflation in the next month, June 2022, can be forecasted using Lee's Fuzzy Time Series method. The prediction result obtained for inflation in June 2022 is 3,66% as shown in Table 7. This shows that inflation in Indonesia in June 2022 is predicted to increase by 0,11% when compared to the period of May 2022.

Table 7 Forecasting for June 2022

Period	Current state	Forecast
June 2022	A_6	3,66

4. Conclusion

Forecasting inflation in Indonesia using Lee's Fuzzy Time Series method using inflation data from January 2017 to May 2022 has a MAPE value of 8,16%. This means that the forecasting error rate of Lee's Fuzzy Time Series method in forecasting inflation in Indonesia has a very good error rate because the MAPE value is $< 10\%$. By using Lee's Fuzzy Time Series method, the prediction result of inflation in Indonesia for the period of June 2022 is 3,66%. This shows that inflation in Indonesia in June 2022 is predicted to increase by 0,11% when compared to the period of May 2022.

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