

## APPLICATION OF THE FUZZY TIME SERIES CHEN MODEL IN FORECASTING THE RUPIAH EXCHANGE RATE AGAINST THE US DOLLAR (USD)

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**Abstract:** *The importance of the rupiah exchange rate for many individuals in Indonesia in everyday life can be explained by the fact that the country's economy is very dependent on the international economy. The exchange rate used to do future payments using a certain currency, and so on, the link between two currencies of different countries. In context In international trade, the US Dollar (USD) currency has a very important role, very significantly for developing countries because it is used as a transaction currency. Therefore, the movement of the rupiah exchange rate is an important factor for a country. So, forecasting techniques are needed to anticipate exchange rate changes. In this study, the method used is Chen's Fuzzy Time Series (FTS) model to predict the rupiah exchange rate against the United States Dollar (USD) in the future. The results of this study show that forecasting the rupiah exchange rate against the US Dollar (USD) from May 2023 to July 2023 is stable at a value of 1412.40 Rupiah, with a rate average absolute error (MAPE) of 1.6717%.*

## 1. INTRODUCTION

The importance of the rupiah exchange rate for many individuals in Indonesia in everyday life can be explained by the fact that this country's economy is highly dependent on the international economy (Elvierayani, 2017). In the modern era, currency has become the main means of financial transactions. The exchange rate or currency exchange rate is a price that fluctuates and is determined by the demand and supply of a country's currency. Currency exchange rates reflect the value of a currency as a means of payment now and in the future. Apart from that, the exchange rate also functions as a link between two currencies from different countries. Each country has a currency unit that is determined in a certain amount (Iwardani dkk., 2021). In the last two years, the Covid-19 pandemic, the inflation rate, demand for exports of goods, and bank interest rates are factors that have caused instability in the rupiah exchange rate against the US dollar. In future estimates, the impact of this instability indicates that the rupiah exchange rate against the US dollar is expected to experience further weakening (Tri dkk., 2020).

Since the outbreak of the corona virus (Covid-19) in Indonesia, the rupiah exchange rate has experienced a significant impact, experiencing a fairly large decline. In 2020, on average, the rupiah exchange rate weakened by 2.26% to Rp. 14,525 per US dollar, compared to Rp. 14,139 per US dollar in 2019. The decline in the rupiah exchange rate against the US dollar has the potential to have an impact on the national economy by triggering inflation. This can result in an increase in the price of goods, especially for products that rely on imported raw materials

in their processing. When the price of goods or services at home relative to prices abroad changes, this can affect the value of foreign currency in the foreign exchange market. To maintain the stability of the rupiah exchange rate, the government can take anticipatory steps to deal with changes in the rupiah exchange rate. One step that can be taken is to forecast or predict the movement of the rupiah exchange rate against the US dollar in the future. By having a more accurate estimate of the possibility of weakening of the rupiah exchange rate, the government can take appropriate anticipatory action. Therefore, to forecast the rupiah exchange rate against the US dollar (USD), various forecasting techniques are used, one of which is time analysis or analysis. time series. Through time analysis, the government and market players can gain insight into potential changes in the rupiah exchange rate. This information will provide the government with a useful basis for making appropriate decisions and steps to manage the consequences of exchange rate changes on the economy and the stability of the country's currency.

Time series analysis refers to a series of observations related to the quantitative properties of one or more events collected sequentially over a specified period of time (Hansun, 2013). One time series analysis method that has advantages over other time series analysis methods is Fuzzy Time Series (FTS). Many FTS methods have been developed, one of which is Chen's fuzzy time series model. Chen's FTS is a method that is different from other fuzzy time series models, especially in the defuzzification process. The defuzzification process in Chen's fuzzy time series model does not see any repetition in the fuzzy logic relationship (FLR) when determining the fuzzy logic relationship group (FLRG).

One of the studies related to the Rupiah Exchange Rate against the US Dollar was carried out by Hidayati & Asikin (2021) by forecasting the rupiah exchange rate against the dollar using the fuzzy time series Markov Chain method. The accuracy value obtained was below 10%, namely with a MAPE value for the selling rate of 0.1379% and the buying rate of 0.1299%. Other research conducted by Hafiyya et al (2022) regarding the application of the fuzzy time series method in forecasting gold prices in Indonesia. The research results showed good results with the gold price for the period 1 July 2022 estimated at IDR 988,313 with a MAPE value of 0.60515%, which indicates that the FTS is very effective in predicting gold prices in Indonesia. Ekananta et al (2018) has also conducted other research which focuses on the application of the average-based fuzzy time series method to predict electricity consumption in Indonesia. The research results show that the prediction accuracy measured using MAPE is 14.27%. These results meet the good criteria, showing the success of this method in predicting electricity consumption in Indonesia. Based on the description provided, in this research the Chen model of the fuzzy time series method will be used to predict the rupiah exchange rate against the US dollar.

## **2. LITERATURE REVIEW**

### **2.1. Data Exploration**

Data exploration is used to determine the data pattern of the rupiah exchange rate against the US dollar (USD). In this research, secondary data regarding the rupiah exchange rate is used against the US dollar (USD), obtained from relevant sources consisting of monthly data on the exchange rate of the rupiah against the US dollar (USD) in January 2020 to April 2023.

## 2.2. Chen's Fuzzt Time Series

Chen's fuzzy time series model is one of the method developments in the field of fuzzy time series. This method is a new, simpler model and is a development of the FTS method first developed by Song and Chissom in 1993. This method was developed to overcome complex calculations in early methods that still involved complex matrix operations. In this method, repetition is not noticed at the time of formation of FLRG. The steps in the algorithm for Chen's fuzzy time series model include (Pramana, 2021):

- i. Defines the set of actual data discussion universes as follows (U)

$$U = [D_{min} - D_1, D_{maks} + D_2] \quad (1)$$

- ii. Determine the number of fuzzy sets using an average based model with the following steps:

- a. Determines the length of the interval ( $R$ ) with the following equation:

$$R = [(D_{maks} + D_2) - (D_{min} - D_1)] \quad (2)$$

- b. Calculate the average absolute difference (lag) value using the following formula:

$$S = \frac{\sum_{t=1}^{n-1} |Y_t - Y_{t-1}|}{n-1} \quad (3)$$

- c. Determine the interval basis with the following formula:

$$B = \frac{S}{2} \quad (4)$$

- d. Calculate the number of fuzzy sets using the following formula:

$$n = \frac{R}{B} \quad (5)$$

- e. To find the middle value of a fuzzy set, the following formula is used:

$$m_i = \frac{Batas\ Bawah\ u_i + Batas\ Atas\ u_i}{2} \quad (6)$$

3. Defining fuzzy sets in the universe set

$$A_i = \mu_{A_i}(u_i)/u_i + \dots + \mu_{A_i}(u_n)/u_n \quad (7)$$

4. Create Fuzzy Logical Relationship (FLR) based on actual data.

5. Determining Fuzzy Logical Relationship Group (FLRG).

6. Defuzzification.

where:

$U$  : The universe set

$\emptyset$  : Empty set

$R$  : Interval length

$t$  : Time index

$Y_t$  : Time  $t$  data

$Y_{t-1}$  : Time-to-date data ( $t - 1$ )

$D_{min}$  : Smallest time data

$D_{max}$  : Largest time data

$S$  : Average absolute difference (lag).

$B$  : Interval basis

$n$  : The number of fuzzy sets

$m_i$  : The mean value of a fuzzy set

$u_i$  :  $i$ th fuzzy set

$u_{i+1}$  : The  $i$ -th fuzzy set after that

$u_{i-1}$  : The previous  $i$ -th fuzzy set

$A_i$  : Fuzzyfication  $i$

- $\mu_{A_i}(u_i)$  : Degree of membership to  $u_i A_i$   
 $\Sigma$  : Overall value  
 $D_i$  : Any positive number  
 $\hat{Y}_t$  : Forecasting value for the t-th period

### 2.3. MAPE

In assessing the accuracy of forecasting methods, Mean Absolute Percentage Error (MAPE) is used as one of the frequently used measures. A forecasting result is considered good if it has a MAPE below 20%, and a forecasting result is considered very good if it has a MAPE below 10% (Robial., 2018). The formula for calculating the MAPE value is as follows:

$$MAPE = \left( \frac{1}{N} \sum_{i=1}^N \frac{|Y_t - \hat{Y}_t|}{Y_t} \times 100\% \right) \quad (8)$$

Where  $Y_t$  is the actual data for the i-period,  $\hat{Y}_t$  is the predicted result for the i-period and n is the number of time periods. Imputation results are very good if the MAPE value is <10%, while the imputation results are good if the MAPE value is between 10% and 20%.

## 3. METHODOLOGY

### 3.1 Data Analysis

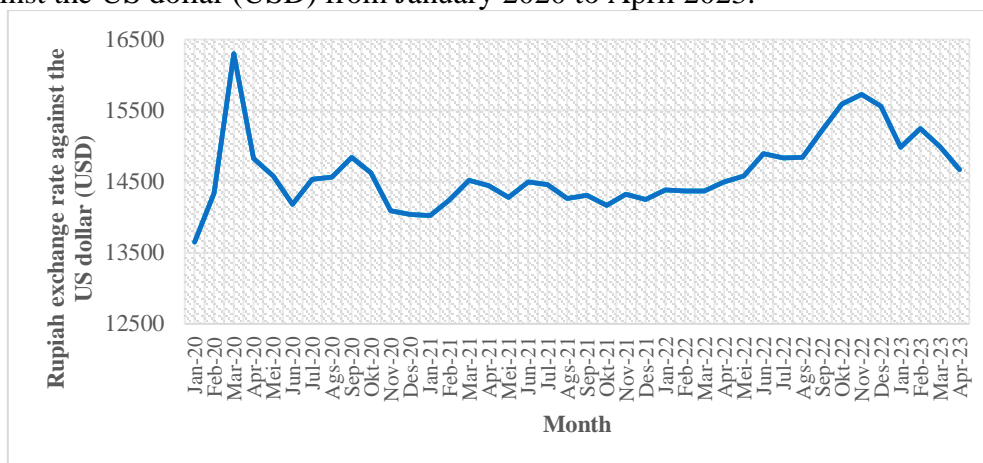
In this research, data analysis was carried out using RStudio and Microsoft Excel Software. Following are the steps involved carried out to analyze the data in this research:

- i. Import data.
- ii. Data exploration. The purpose of data exploration is to recognize patterns contained in data regarding the Rupiah exchange rate against the American Dollar (USD).
- iii. Formation of a universal association. The universe was formed taking into account the minimum value, maximum value, as well as the values of  $D_1$  and  $D_2$  are determined by the researcher.
- iv. Determine the number of fuzzy sets. Many groups have been formed in the model is determined using the method approach based on averages (average based).
- v. Define fuzzy sets and fuzzyfication. Definition Fuzzy sets and fuzzyfication have the aim of changing data numeric into linguistic data with the intent to convey the data.
- vi. Form Fuzzy Logical Relationships (FLR). RANGE is formed based on historical data that has been converted into a fuzzy set at the previous stage.
- vii. Determine the Fuzzy Logical Relationship Group (FLRG). FLRG formed based on the F formed.
- viii. Defuzzification. Defuzzification is carried out to change the fuzzy output into a definite (numerical) value, thus producing an approximate value which can be used.
- ix. Evaluate Prediction Results and Carry Out Forecasting. Evaluation of Results Predictions are made using Mean Absolute Percentage Error (MAPE).
- x. Interpret forecasting results.
- xi. Conclusion.

## 4. RESULT AND DISCUSSION

### 4.1. Exploration Data

Data exploration is used to determine the data pattern of the rupiah exchange rate against the US dollar (USD). The following is a graph showing the data pattern of the rupiah exchange rate against the US dollar (USD) from January 2020 to April 2023.



**Figure 1.** Time Series Plot Rupiah Exchange Rate (USD)

Based on Figure 1. it can be seen that data on the rupiah exchange rate against the US dollar (USD) shows a high level of volatility or experiences frequent changes in a short time span. This can be seen from the exchange rate fluctuations depicted in the graph. The following are the steps in forecasting Rupiah exchange rate against US dollar (USD) using Chen's fuzzy time series model method.

### 4.2. Formation of the Universal Set

Data on the exchange rate of the rupiah against the US dollar (USD) for the period January 2020 to April 2023 shows that the lowest rupiah exchange rate is IDR 13,650 and the highest is IDR 16,300. then the values  $D_1$  determined  $D_2$  by the researcher are respectively 25 and 25.19. So the universal set is obtained as follows:

$$\begin{aligned}
 U &= [D_{min} - D_1; D_{max} + D_2] \\
 &= [13650 - 25 ; 16300 + 25,19] \\
 &= [13625 ; 16325,19]
 \end{aligned}$$

### 4.3. Determining the Number of Fuzzy Sets

of fuzzy sets is calculated using an average based method. The steps in determining fuzzy sets are as follows:

1. Calculates the length of the interval ( $R$ ) from the set of conversational universes( $U$ )

$$\begin{aligned}
 R &= (D_{max} + D_2) - (D_{min} - D_1) \\
 &= (16300 + 25,19) - (13650 - 25) \\
 &= 16325,19 - 13625
 \end{aligned}$$

$$= 2700,19$$

2. Calculate the average absolute difference for each data( $S$ )

To get the average absolute difference calculations are carried out by adding up the absolute differences between the data . The absolute difference in actual data can be seen in Table 1.

**Table 1.** Absolute Difference in Data Rupiah Exchange Rate ( USD )

No	Period	NTR (USD)	$ Y_t - Y_{t-1} $
1	Jan 2020	13650	0
2	February 2020	14340	690
3	March 2020	16300	1960
4	April 2020	14825	1475
⋮	⋮	⋮	⋮
40	April 2023	14665	325
<b>count</b>			11085

Based on Table 1, the absolute difference in data is 11085. Next, calculations are carried out to get the average absolute difference value for each data .

$$\begin{aligned}
 S &= \frac{\sum_{t=1}^{n-1} |(Y_{t-1}) - Y_t|}{40 - 1} \\
 &= \frac{11085}{39} \\
 &= 284,23
 \end{aligned}$$

3. Calculating the interval basis of *fuzzy sets*( $B$ )

$$\begin{aligned}
 B &= \frac{S}{2} \\
 &= \frac{284,23}{2} \\
 &= 142,115
 \end{aligned}$$

4. Counting the number of *fuzzy sets*( $n$ )

$$\begin{aligned}
 n &= \frac{R}{B} \\
 &= \frac{2700,19}{142,115} \\
 &= 19
 \end{aligned}$$

5. *fuzzy sets* ( $u$ )

Based on the calculation of the number of fuzzy sets , the result is that the number of *fuzzy sets* is 19 sets with an interval length of 142,115 .  $U$  in each *fuzzy set* is partitioned into 19 sets. So the *fuzzy set* formed is as follows.

$$\begin{aligned}
 u_1 &= [13625,00; 13767,12] \\
 u_2 &= [13767,12; 13909,23]
 \end{aligned}$$

$$\begin{aligned}
 u_3 &= [13909,23; 14051,35] \\
 u_4 &= [14051,35; 14193,46] \\
 u_5 &= [14193,46; 14335,58] \\
 &\vdots \\
 u_{18} &= [16040,96; 16183,08] \\
 u_{19} &= [16183,08; 16325,19]
 \end{aligned}$$

After obtaining the fuzzy sets, the middle value for each set can be determined. Results of calculating the mean value of the *fuzzy set*  $m_i$  presented in Table 2 below.

**Table 2.** Middle Value of *Fuzzy Sets*

<i>Fuzzy Set</i>	<b>Middle value ( <math>m_i</math> )</b>
$u_1$	13696.06
$u_2$	13838.17
$u_3$	13980.29
$u_4$	14122.40
$u_5$	14264.52
$\vdots$	$\vdots$
$u_{18}$	16112.02
$u_{19}$	16254.13

**4.4. Defining Degrees of Membership of Fuzzy  $A_i$  Sets and Fuzzyfication**

Determining the degree of membership of a *fuzzy set* is  $A_i$  based on the *fuzzy set* that is formed. The following is the definition of *fuzzy sets* for  $A_i$ .

$$\begin{aligned}
 \mu_{A_1(u_1)} &= 1/u_1 + 0,5/u_2 + 0/u_3 + \dots + 0/u_{19} \\
 \mu_{A_2(u_2)} &= 0,5/u_1 + 1/u_2 + 0,5/u_3 + \dots + 0/u_{19} \\
 \mu_{A_3(u_3)} &= 0/u_1 + 0,5/u_2 + 1/u_3 + \dots + 0/u_{19} \\
 \vdots &= \vdots + \vdots + \vdots + \dots + \vdots \\
 \mu_{A_{19}(u_{19})} &= 0/u_1 + 0/u_2 + 0/u_3 + \dots + 1/u_{19}
 \end{aligned}$$

*fuzzy set* membership of  $A_i$ , the following *fuzzyfication results* are obtained

**Table 3.** *Fuzzyfication results*

<i>Fuzzyfication</i>	<b>Linguistic Values</b>
$A_1$	Level 1
$A_2$	Level 2
$A_3$	Level 3
$A_4$	Level 4
$A_5$	Level 5
$\vdots$	$\vdots$
$A_{18}$	Level 18
$A_{19}$	Levels 19

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Description: The process of naming linguistic value levels is based on a sequence of *fuzzy set interval values* . The smaller the *fuzzy set interval value* , the smaller the linguistic value level , so the more drastic the decline in the rupiah exchange rate data against the US dollar (USD).

*fuzzyfication* results in Table 3, the *fuzzyfication process* for the rupiah exchange rate data against the US dollar (USD) for the period January 2020 to April 2023 is presented in Table 4.

**Table 4. Fuzzification of NTR ( USD) Data**

Period	NTR USD (Rupiah)	Fuzzyfication	Levels
Jan 2020	Rp. 13650	$A_1$	Level 1
February 2020	Rp. 14340	$A_6$	Level 6
March 2020	Rp. 16300	$A_{19}$	Level 19
April 2020	Rp. 14825	$A_9$	Level 9
⋮	⋮	⋮	⋮
April 2023	Rp. 14665	$A_8$	Level 8

**4.5. Determination of Fuzzy Logical Relationship (FLR)**

Determining *Fuzzy Logical Relationship* (FLR) involves 1 historical data symbolized by  $Y_{t-1} \rightarrow Y_t$ . The results of FLR data on the rupiah exchange rate against the US dollar (USD) are presented in Table 5.

**Table 5. FLR Rupiah ( USD ) Exchange Rate Data**

Period	FLR	Levels
Jan 2020	-	-
February 2020	$A_1 \rightarrow A_6$	Level 1 $\rightarrow$ Level 6
March 2020	$A_6 \rightarrow A_{19}$	Level 6 $\rightarrow$ Level 19
April 2020	$A_{19} \rightarrow A_9$	Level 19 $\rightarrow$ Level 9
⋮	⋮	⋮
April 2023	$A_{10} \rightarrow A_8$	Level 10 $\rightarrow$ Level 8

**4.6. Formation of Fuzzy Logical Relationship Group (FLRG) and Weighting**

The formation of the *fuzzy logical relationship group* (FLRG) has the same steps as the FLR formation stage on the rupiah exchange rate data against the US dollar (USD) . *Fuzzyfication* groups that have the same *current state* are then grouped into one next state group . In the Chen model *fuzzy time series* method, recurrence is not taken into account when grouping FLR. FLRG results data on the rupiah exchange rate against the US dollar (USD) presented in Table 6 .

**Table 6. FLRG Rupiah ( USD ) Exchange Rate Data**

Group	FLRG
1	$A_1 \rightarrow A_6$



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2	$A_2 \rightarrow \emptyset$
3	$A_3 \rightarrow A_3, A_5$
4	$A_4 \rightarrow A_3, A_5, A_7$
⋮	⋮
19	$A_{19} \rightarrow A_9$

**4.7. Defuzzification**

In the *defuzzification process*, the calculation process uses Chen's (1996) rules . Thus, the results of the *defuzzification* of forecast values from the 19 groups formed are presented in Table 7.

**Table 7.** Results of *Defuzzification of Forecast Values*

Group	FLRG	Defuzzification
1	$A_1 \rightarrow A_6$	14406.63
2	$A_2 \rightarrow \emptyset$	13838.17
3	$A_3 \rightarrow A_3, A_5$	14122.40
4	$A_4 \rightarrow A_3, A_5, A_7$	14264.52
⋮	⋮	⋮
19	$A_{19} \rightarrow A_9$	14832.98

**4.8. Evaluate Prediction Results and Perform Forecasting**

The rupiah exchange rate against the US dollar (USD) from January 2020 to April 2023 was obtained through the FLRG group *de-fuzzing process* . To get the predicted value for the *t- th time period* ( $Y_t$ ), used previous data  $Y_{t-1}$  that has been given a *fuzzy* fication value. Prediction results are presented in Table 8.

**Table 8.** Rupiah Exchange Rate (USD) Prediction Results

No	Fuzzyfication	NTR USD (Rupiah)	Prediction
1	$A_1$	Rp. 13650	-
2	$A_6$	Rp. 14340	Rp. 14406.63
3	$A_{19}$	Rp. 16300	Rp 14868.51
4	$A_9$	Rp. 14825	Rp. 14832.98
⋮	⋮	⋮	⋮
40	April 2023	$A_8$	Rp. 14665

The next step is to see the accuracy of the prediction results by calculating the MAPE value of the FTS predictions from the Chen model. The calculation of the MAPE value from the FTS Chen model prediction results can be seen in Table 9.

**Table 9.** Calculation of MAPE Values from Prediction Results

No	Period	Fuzzyfication	$Y_t$	$\hat{Y}_t$	$\frac{ Y_t - \hat{Y}_t }{Y_t}$
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**Putri et al , Application of The Fuzzy Time Series Chen Model in Forecasting  
The Rupiah Exchange Rate Against The Us Dollar (USD)**

1	Jan 2020	$A_1$	13650	-	-
2	February 2020	$A_6$	14340	14406.63	0.465
3	March 2020	$A_{19}$	16300	14868.51	8,782
4	Apr 2020	$A_9$	14825	14832,98	0,054
⋮	⋮	⋮	⋮	⋮	⋮
40	Apr 2023	$A_8$	14665	14975,10	2,115
$\sum_{t=2}^{40} \frac{ Y_t - \hat{Y}_t }{Y_t}$					65,196
$MAPE = \left( \frac{1}{N} \sum_{i=1}^N \frac{ Y_t - \hat{Y}_t }{Y_t} \times 100\% \right)$					1,6717%

Based on Table 9, the MAPE value obtained from the rupiah exchange rate data against the US dollar (USD) is 1.67 17 %. The MAPE value shows that the prediction results are categorized as very good because the value is less than 10%. Then forecast the exchange rate of the rupiah against the US dollar (USD) for the next three month period, namely from May 2023 to July 2023 , the forecasting results are presented in Table 10.

**Table 10.** Rupiah (USD) Exchange Rate Forecasting Results

Period	<i>Fuzzyficati on</i>	Forecasting
May 2023	$A_8$	14122.40
June 2023	$A_8$	14122.40
July 2023	$A_8$	14122.40

#### 4.9. Interpretation of Forecasting Results

Based on the prediction and forecasting results obtained, a *time series plot can be made* comparing the prediction results and actual data as well as the forecasting results and actual data on the rupiah exchange rate against the US dollar (USD) . *Time series* plot image of actual data and predicted data on the rupiah exchange rate against the US dollar (USD) presented in Figure 2.

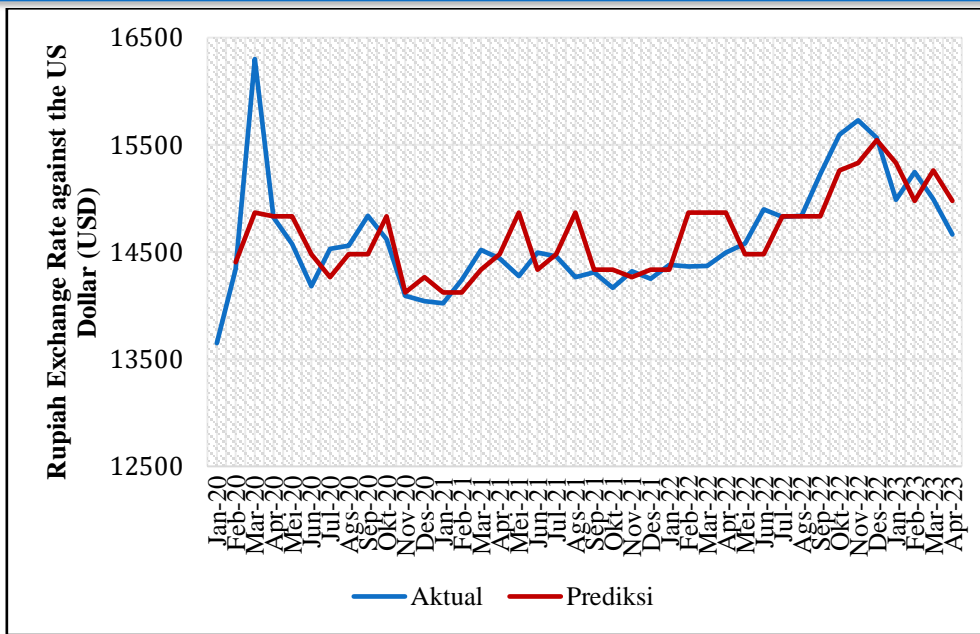


Figure 2. Time Series Plot Comparison of Prediction Results and Actual Data

Based on Figure 2, it can be seen that *the time series plot* predicts the results Chen model FTS **tends to be close to the time series plot** of actual data on the rupiah exchange rate against the US dollar (USD) . This indicates that the Chen model FTS method very good for use in forecasting the rupiah exchange rate against the US dollar (USD) . The *time series plot* of actual data and data from forecasting the rupiah exchange rate against the US dollar (USD) presented in Figure 3.

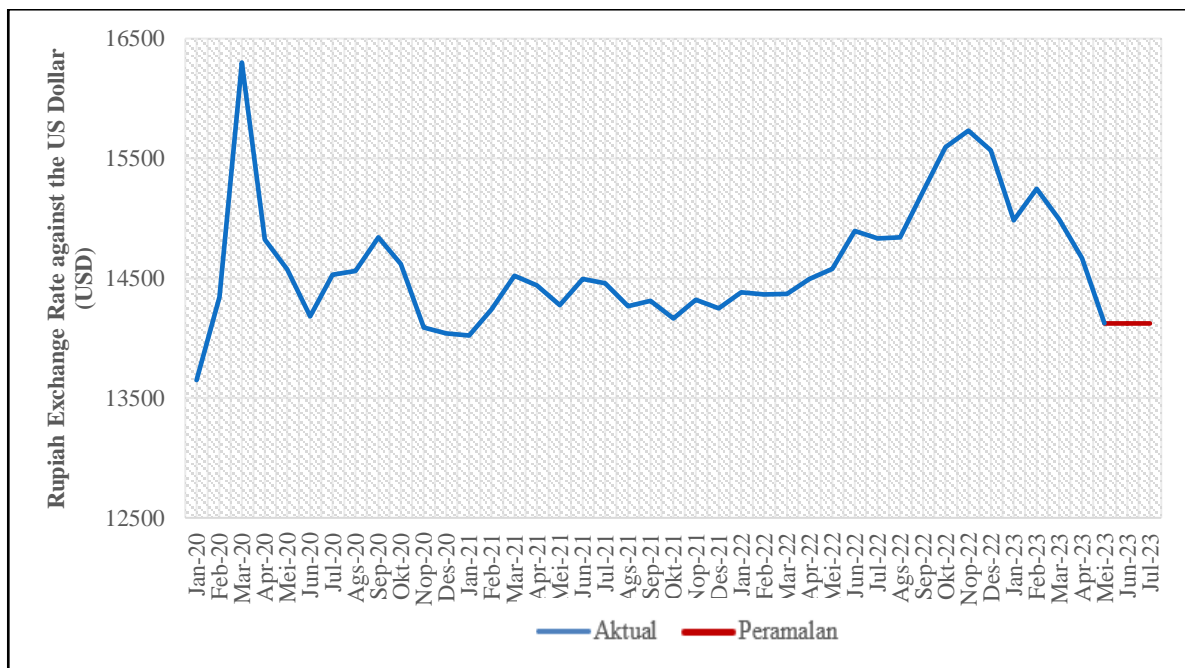


Figure 3. Time Series Plot of Forecasting Results

Based on Figure 3, the forecast results obtained show the exchange rate of the rupiah against the US dollar (USD). is at level 8, which is IDR 14 . 122.40. . The downward trend in

the rupiah exchange rate against the US dollar (USD) has the potential to have a negative impact on the government and the national economy. This situation can cause inflation and increase the price of goods, especially for goods or products that use imported raw materials. Fluctuations in the rupiah exchange rate are influenced by several factors, such as the demand and supply of money, the amount of money in circulation, government policies, and other factors. If this condition continues, the weakening of the rupiah exchange rate could result in an increase in production costs and potentially hamper company performance, especially for companies that import raw materials for their production.

## 5. CONCLUSION

Based on the results and discussions that have been carried out previously, it can be concluded that the results of forecasting the rupiah exchange rate against the US dollar (USD) for the next three month period, namely from May 2023 to July 2023 using the *fuzzy time series* method the Chen model consistently has a value of Rp. 14,122.40 with a level of accuracy of forecasting results using MAPE of 1.6717 % .

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