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PREDICTION OF THE CURRENCY EXCHANGE RATE USING FUZZY TIME SERIES

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ABSTRACT

The exchange rate is the price of one currency in relation to another currency, expressed as a percentage. There is also a potential for fixed or dynamic exchange rates. Even though central banks control fixed exchange rates, the market determines floating exchange rates by the supply and demand of goods and services, not by the supply and demand of money. The main objective of this study is to predict the currency exchange rate from 1st July 2019 to 29th July 2022. The sub-objectives are to predict the currency exchange rate by using the Fuzzy Time Series and to check the accuracy of the prediction of the exchange rate by using Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE). This study can help many sectors in Malaysia, such as governments, investors, and communities. Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE) are used to evaluate this method's performance. The results show that Fuzzy Time Series produce a good forecast result because the analysis shows that Fuzzy Time Series have the lowest value of RMSE and MAPE which is below then one.

Keywords*: Exchange rate, Fuzzy Time Series, MAPE, RMSE*

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1. Introduction

This chapter will summarize the research. The first section of this chapter will discuss the background of the research, which is connected to the exchange rate. Not only that, but this chapter will also include a problem statement outlining the issue that will be resolved. Following that, the remainder of this chapter will discuss the objective of this study, its scope, and its significance.

1.1. Background of study

The exchange rate is the price of one currency expressed as a percentage of another currency. There is also the possibility of fixed or variable exchange rates. Even though central banks control fixed exchange rates, the market determines floating exchange rates based on the supply and demand of goods and services, not money (The Economic Times, 2022, June 29). The value of a country's currency in proportion to the value of another country's currency or the value of an economic zone's currency is another definition of an exchange rate. Most currency exchange rates are free-floating, which means they fluctuate in

response to supply and demand changes on global financial markets. In certain cases, exchange rates may be tied to the value of other currencies and subject to government administration or regulation. This is a conceivable scenario.

Financial institutions have risen to the top of the global currency market because of the growth of the international economy, where they currently occupy a dominant position. When it comes to open economies, exchange rates are a key macroeconomic indicator since they influence the choices of businesses on whether to invest in foreign markets. The effect of foreign currency rates on imports and exports directly impacts the strategy's success in reducing the international trade deficit necessitates the examination of this alternative. All of these elements of the modern world, including international trade, global economic trends, global trade in goods and services, and the global movement of labor, technology, and money, have an effect on the economies of all nations, regardless of their physical location. International trade, global economic trends, and the movement of goods and services worldwide all impact the economies of countries worldwide in the modern world, regardless of where they are physically located. If a trade transaction involves multiple locations, currency conversions may be necessary at various points during the transaction.

It is the process of selling products and services to customers in other nations after they have been sourced or manufactured in the home country. The act of importing is the opposite of the act of exporting. In the business world, importation is purchasing products and services from overseas providers and redistributing them inside a country's borders. The terms 'importing' and 'global sourcing' are sometimes used interchangeably when referring to the same thing. Business's export is the quickest and most cost-effective method of entering global trade. It requires less capital investment than the other entry strategies. According to the International Trade Administration, it is much easier to stop exporting than it is to abandon the other entry methods. Due to increased manufacturing numbers, exporting opens the door to new markets, income streams, and cheaper manufacturing costs.

1.2. Problem Statement

The daily currency exchange rates are available at any time. But these daily historical data are less meaningful if no analysis is done on the data. The currency exchange rate needs to be forecasted so that the behavior of the currency can be studied. It is mainly because the currency exchange rate is the most determinant of the country's relative economic situation. The analysis will be beneficial as input for the country, government, investors, and communities to make better decisions for minimizing the risks and maximizing the returns. Many forecasting methods can be used in the study, but not all methods will give the highest accuracy. The problem of the study is to predict the currency exchange rate. In this study, only one method was used to analyze the data, which is the Fuzzy Time Series.

1.3. Objectives

The main objective of this study is to predict the currency exchange rate from 1st July 2019 to 29th July 2022. The sub-objectives are:

I. To predict the currency exchange rate by using Fuzzy Time Series.

II. To check the accuracy of the prediction of the exchange rate by using Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE).

1.4. Scope of Study

This study will focus on the exchange rate of Ringgit Malaysia (RM) with United States Dollar (USD), British Pound Sterling (GDP), euro (EUR), and Australian Dollar (AUD). The data will be predicted using Fuzzy Time Series. This method will be used to predict the exchange rate. The exchange rate data will start on 1st July 2019 until 29th July 2022, and the data has been taken from the Bank Negara Malaysia website.

1.5. Significant

This study will focus on predicting the exchange rate using the Fuzzy Time Series. This study can also help to clearly explain the application of the method and the exchange rate. Government, investors, and communities are three major parties that can benefit from this study.

1.5.1. Government

The presence of a fixed exchange rate makes it simpler to ensure that money transfers easily from one country to another across borders. As a result, attracting foreign investment into developing and developing-country economies is easier. It also contributes to the avoidance of devaluation in developing countries. Many countries do commerce in their currency to control inflation at a consistent level.

The government has fixed the exchange rate. If the currency rate is fixed, the government may likely be discouraged from adopting extreme or hazardous macroeconomic policies because of this. Due in part to the fact that, in the long run, these measures would result in an unsustainable depletion of foreign currency reserves. The objective of a fixed exchange rate system is to restrict the range of possible currency values. In addition to providing greater predictability, the government benefits from fixed exchange rates by helping to keep inflation under control.

1.5.2. Investor

In the short term, finite exchange rates give the major economic advantage of stimulating international business and investment, which in the long run, particularly for emerging countries, may be a key source of development. The value of imported commodities would inevitably vary in value as exchange rates fluctuate, especially for domestic items that are dependent on imported components and raw materials (Picardo, E. nd.). Besides that, exchange rates influence the performance of investments, interest rates, and inflation—and they may even impact other aspects of the economy, such as the labor market and the real estate businesses.

For a variety of reasons, the exchange rate is critical to the economy. A wide variety of commodities, services, and financial assets are traded on the exchange, and it serves as the primary link between the local and worldwide markets for these products. Comparing the price of items, services, and assets that are provided in different currencies is possible by referring to the exchange rate between the two currencies in question. Enterprises will always know the exchange rate if there is a stable exchange rate, which decreases the risk involved with trade and investment.

1.5.3. Communities

Exchange rate changes may not seem to significantly impact most people's daily lives, but the indirect consequences of exchange rate variations are much more pervasive than most of the public is aware of. Aside from that, exchange rates influence the performance of investments, interest rates, and inflation. Depending on the country, they may even impact other parts of the economy, such as the labor market and the real estate industry.

According to a general definition, local currencies are used and traded primarily inside a certain geographic area or community. They are used in combination with official legal money to give an extra source of cash for transactions. They are well-known to most local retailers, and they incentivise citizens to patronise their immediate neighbours' businesses and organisations. A single town or area's local currencies may help to improve and decarbonize the local economy by eliminating the need for foreign money. This helps to reduce greenhouse gas emissions. They contribute to the development of community spirit while simultaneously reducing people's carbon footprints and strengthening the overall resilience of the local community. Local currencies must be recognized as legal tender in order to coexist with the official currency of a given location.

1.6. Summary

Here, the exchange rate is explained in a succinct manner. In other words, it is the cost of one currency expressed as a percentage of the cost of another currency in question. The price of one currency in terms of another currency is converted to arrive at the exchange rate. Furthermore, fixed or variable exchange rates might be a realistic option. Although central banks maintain fixed exchange rates, the market's supply and demand for goods and services determine floating exchange rates, as opposed to the economy's supply and demand for money. Exchanging currencies converts one currency into another, either inside or between countries or economic zones. The term "exchange rate" is used to describe this process. The government, investors, and local communities benefit from the exchange rate.

2. Methodology

This chapter will discuss the research methods available for this study. The first section of this chapter will discuss this study's data collection method. The data will be analyzed using Fuzzy Time Series. Likewise, this chapter also presents the method of data analysis.

2.1. Method of Data Collection

This research used the Bank Negara Malaysia website to get the secondary data needed. For the period from 1st July 2019 to 29th July 2022, the data will be collected. The data will be secondary data because the data related to the exchange of Ringgit Malaysia (RM) with United States Dollar (USD), British Pound Sterling (GBP), euro (EUR), and Australian Dollar (AUD). Fuzzy time series are being used to try to make predictions about the value of the dollar against the other major currencies.

2.2. Method of Data Analysis

The method that has been chosen in this study is the Fuzzy Time Series. According to fuzzy set theory, a specific element may belong to or not belong to the same set to a certain degree. Figure 1 shows the steps to apply fuzzy time series in analyzing the data.

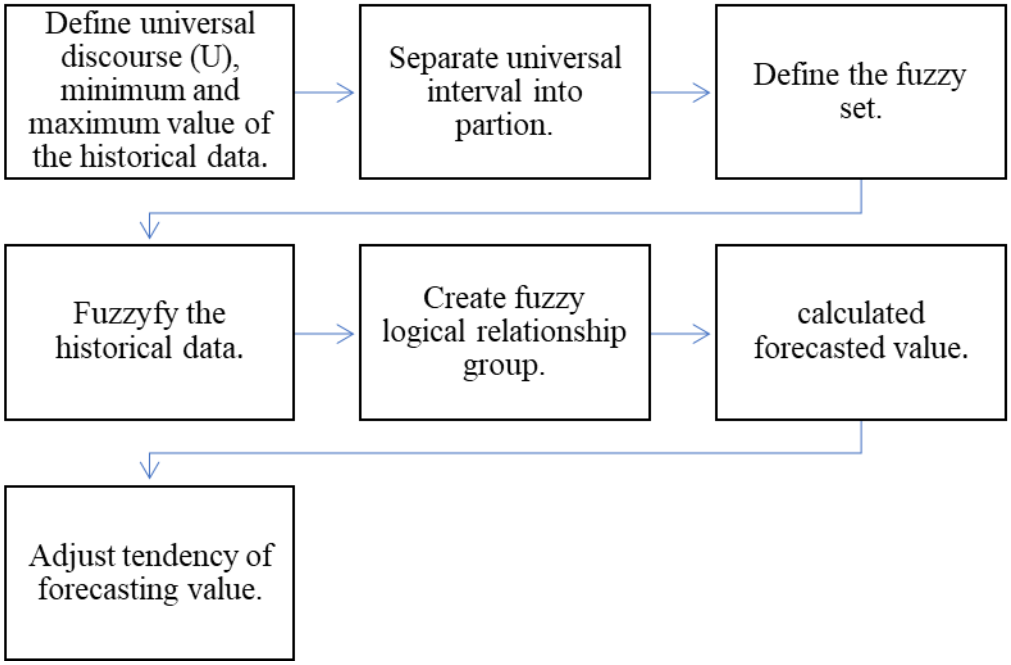

Figure 2.1: Flowchart of fuzzy time series

The followings are the details of the fuzzy time series approach in analyzing the data.

Step 1: Define the universal discourse U, minimum data (D_{min}) and maximum data (D_{max}) for the historical data. The universal discourse is defined as:

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

Step 2: Separate *U* into several equal intervals. The universal discourse is then divided into 7 equal-length intervals with $l = 0.1003$.

Step 3: Define the fuzzy set using the equation.

$$A_1 = \frac{a_{11}}{u_1} + \frac{a_{12}}{u_2} + \ldots + \frac{a_{1n}}{u_n},$$

$$A_2 = \frac{a_{21}}{u_1} + \frac{a_{22}}{u_2} + \ldots + \frac{a_{2n}}{u_n},$$

$$A_k = \frac{a_{k1}}{u_1} + \frac{a_{k2}}{u_2} + \ldots + \frac{a_{kn}}{u_n}, \quad (2)$$

where $Ai\ , i = 1, \ldots, k$ are the fuzzy sets which are represented as linguistic values of the linguistic variables.

Step 4: Fuzzify the historical data due to fuzzy set A_I and create a fuzzy logical relationship group.

Step 5: Calculate the forecasting value, $f(t)$, according to the rules.

Rule 1: If $Y(t-1) = A_i$ and it is a one-to-one fuzzy logical relationship, $A_i \rightarrow A_k$, the forecasted future value, $f(t)$ is calculated by using the equation

$$f(t) = m_k \quad (3)$$

Rule 2: If $Y(t-1) = A_i$ and it is a one-to-many fuzzy logical relationship, for example $A_i \rightarrow A_1, A_2, \ldots, A_n j = 1,2, \ldots, n,$ the forecasted future value, $f(t)$ is:

$$F(t) = m_1 P_{j1} + m_2 P_{j2} + \cdots + m_{j-1} P_{(j-1)} + Y(t-1) P_{jj} + m_{j+1} P_{j(j+1)} + \ldots + m_n P_{jn}, \quad (4)$$

where,

$m_i = midpoint\ of\ interval\ u_i$

$P_{jn} = probability\ from\ state\ j\ to\ state\ n$

Step 6: Adjust the tendency of the forecasting value according to the rules.

Rule 1: If A_i communicates with A_i and makes an increasing transition, where $Y(t-1) = A_i, Y(t), A_j(A_i \to A_j, i > j),$ then the adjusted trend value will be:

$$D_{t1} = \frac{I}{2} \tag{5}$$

Rule 2: If A_i communicates with A_i and makes a decreasing transition, where $Y(t-1) = A_i, Y(t), A_j(A_i \to A_j, i > j),$ then the adjusted trend value will be:

$$D_{t1} = -\frac{I}{2} \tag{6}$$

Rule 3: If $Y(t-1) = A_i$ and makes a jump-forward transition at time t where $Y(t) = A_{i+s}, (1 \leq s \leq n-i),$ then the adjusted trend value will be:

$$D_{t2} = \frac{I}{2}(s) \tag{7}$$

Rule 4: If $Y(t-1) = A_i$ and makes a jump-forward transition at time t where $Y(t) = A_{i+s}, (1 \leq s \leq n-i),$ then the adjusted trend value will be:

$$D_{t2} = \frac{I}{2}(s) \tag{8}$$

Step 7: Calculate the adjusted forecasting values.

$$F'(t) = F(t) \pm D_{t1} \pm D_{t2} \tag{9}$$

One (or more) random variables may be represented by a time series, a collection of data. The order in which they were collected must be considered when assessing them as a distinguishing feature of this variable. This dynamic process is referred to as a fuzzy time series. Fuzzy relational equations are used as models to describe fuzzy temporal information. Time-variant and time-invariant fuzzy time series are the two types of fuzzy time series. This course discusses some of the characteristics and methodologies for developing fuzzy time series models. Finally, a method for forecasting uncertain time series is presented.

2.3. Accuracy Test

To determine the currency exchange rate's accuracy, the result from the method is evaluated using Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE).

$$RMSE = \frac{1}{n}\sqrt{\sum_{i=1}^{n}(P(t) - F(t))^2}$$

where,

P(t) = actual value

F(t) = prediction

n = sample size

t = timestamp

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{P(t) - F(t)}{P(t)}\right| \times 100$$

where,

P(t) = actual value

F(t) = forecast value

n = sample size

2.4. Summary

In short, this chapter briefly explains the method of data collection and the methods used in analyzing the data. The data used in this study is secondary data collected from the Bank Negara Malaysia website. This chapter also explains more about the method of data analysis which is fuzzy time series.

3. Result and Discussion

This chapter will explain the result of forecasting the exchange rate of Ringgit Malaysia (RM) with United States Dollar (USD), British Pound Sterling (GDP), Euro (EUR), and Australian Dollar (AUD) by using the Fuzzy Time Series. In addition, RMSE and MAPE are applied to determine the accuracy exchange rate.

3.1. Data Collection

The secondary data used in this study were the daily exchange rate of Ringgit Malaysia (RM) with United States Dollar (USD), British Pound Sterling (GDP), Euro (EUR), and Australian Dollar (AUD) from July 1, 2019, to July 29, 2022. This data is available at https://www.bnm.gov.my/exchange-rates. Table 4.1 below shows the daily price of the exchange rate of Ringgit Malaysia (RM) with United States Dollar (USD), British Pound Sterling (GDP), Euro (EUR), and Australian Dollar (AUD) from July 1, 2019, to July 29, 2022.

Table 3.1: Daily price of the exchange rate of Ringgit Malaysia (RM) with United States Dollar (USD), British Pound Sterling (GDP), Euro (EUR), and Australian Dollar (AUD) from July 1, 2019, to July 29, 2022.

Date	Exchange Rate			
	USD	GBP	EUR	AUD
1 July 2019	4.1335	5.2491	4.6928	2.8945
2 July 2019	4.1420	5.2347	4.6722	2.8890
3 July 2019	4.1405	5.2133	4.6734	2.8973
…	…	…	…	…
27 Dec 2019	4.1315	5.3707	4.5938	2.8735
30 Dec 2019	4.1135	5.3957	4.6069	2.8749
31 Dec 2019	4.0925	5.3722	4.5852	2.8660
2 Jan 2020	4.0865	5.3983	4.5824	2.8632
3 Jan 2020	4.0995	5.3853	4.5800	2.8565
6 Jan 2020	4.1080	5.3743	4.5870	2.8518
…	…	…	…	…
29 Dec 2020	4.0510	5.4660	4.9590	3.0780
30 Dec 2020	4.0400	5.4694	4.9623	3.0884
31 Dec 2020	4.0130	5.4653	4.9324	3.0896
4 Jan 2021	3.9965	5.4736	4.8971	3.0841
5 Jan 2021	4.0065	5.4430	4.9174	3.0846
6 Jan 2021	4.0145	5.4601	4.9322	3.1108
…	…	…	…	…
29 Dec 2021	4.1815	5.6172	4.7278	3.0241
30 Dec 2021	4.1705	5.6248	4.7283	3.0267
31 Dec 2021	4.1760	5.6361	4.7256	3.0289
3 Jan 2022	4.1710	5.6306	4.7335	3.0233
4 Jan 2022	4.1815	5.6302	4.7241	3.0119
5 Jan 2022	4.1905	5.6710	4.7336	3.0318
…	…	…	…	…
27 July 2022	4.4600	5.3743	4.5236	3.0870
28 July 2022	4.4550	5.4193	4.5486	3.1165
29 July 2022	4.4485	5.4234	4.5433	3.1175

3.2. Data Analysis Using Fuzzy Time Series

To predict the daily price of the exchange rate of Ringgit Malaysia (RM) with United States Dollar (USD), British Pound Sterling (GDP), Euro (EUR), and Australian Dollar (AUD), the following steps are proposed by Cheng's Model are followed (Cheng et al, 2008):

Step 1: The universe of discourse and fuzzy intervals need to be defined. The universe is defined as

$$U = [(U_{min} - D_1), (U_{max} + D_2)]$$

Where U_{min} and U_{max} represent the minimum and maximum value of the historical data of the daily price of the exchange rate. Both D_1 and D_2 are chosen to divide the interval evenly. From the formula above, for the United States Dollar (USD), based on the data, the minimum value of the data $U_{min} = 3.9965,$ and the maximum value of the data $U_{max} = 4.4600$. For the British Pound Sterling (GBP), the minimum value of the data $U_{min} = 5.0162$ and the maximum value of data $U_{max} = 5.8984$. For the Euro (EUR), the minimum value of the data $U_{min} = 4.4479,$ and the maximum value of data $U_{max} = 5.0677.$ For the Australian Dollar (AUD), the minimum value of the data $U_{min} = 2.4487$ and the maximum value of data $U_{max} = 3.2239$. D_1 and D_2 are a positive number which for this study the value of D_1 and D_2 are 0.

The calculation for the universe of discourse U is determined as:

USD	GBP
$U = [(U_{min} - D_1), (U_{max} + D_2)]$ $U = [(3.9965 - 0), (4.4600 + 0)]$ $U = [3.9965, 4.4600]$	$U = [(U_{min} - D_1), (U_{max} + D_2)]$ $U = [(5.0162 - 0), (5.8984 + 0)]$ $U = [5.0162, 5.8984]$
EUR	AUD

$U = [(U_{min} - D_1), (U_{max} + D_2)]$ $U = [(4.4479 - 0), (5.0677 + 0)]$ $U = [4.4479, 5.0677]$	$U = [(U_{min} - D_1), (U_{max} + D_2)]$ $U = [(2.4487 - 0), (3.2239 + 0)]$ $U = [2.4487, 3.2239]$

So, the intervals for the fuzzy set for the United States Dollar (USD) will start at 3.9965 and end at 4.4600, for British Pound Sterling (GBP) will start at 5.0162 and end at 5.8984. Euro (EUR) will start at 4.4479 and end at 5.0677, and for Australian Dollar (AUD) will start at 2.4487 and end at 3.2239. the number of linguistic intervals can be calculated by using Sturges Formula:

$$k = 1 + 3.322 \log 10\ (n)$$

$$k = 1 + 3.322 \log 10\ (760)$$

$$k = 10.57006275$$

$$k \approx 11$$

Thus, the number of the intervals is 11, and they are denoted as A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8, A_9, A_{10}, and A_{11} like in the fuzzy set's interval table (table 3.3).

Table 3.2: Linguistic Description Table

A_1	Lowest Exchange Rate
A_2	Very Low Exchange Rate
A_3	Moderate Exchange Rate
A_4	Little Low Exchange Rate
A_5	Low Exchange Rate
A_6	Regular Exchange Rate
A_7	High Exchange Rate

A_8	Little High Exchange Rate
A_9	Moderate Exchange Rate
A_{10}	Very High Exchange Rate
A_{11}	Highest Exchange Rate

Step 2: Separate U into several equal interval. There will be a dividing process to separate $A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8, A_9, A_{10}$, and A_{11} into equals intervals between them by using this formula:

$$l = \frac{(U_{max} + D_2) - (U_{min} - D_1)}{k}$$

where;

$l =$ The length of an intervals

$k =$ Number of intervals

Based on the previous calculation, the value of k is 11 and the calculation will be as follow:

USD $l = \frac{(4.4600+0)-(3.9965-0)}{11}$ $l = \frac{(4.4600)-(3.9965)}{11}$ $l = 0.0421$	GBP $l = \frac{(5.8984+0)-(5.0162-0)}{11}$ $l = \frac{(5.8984)-(5.0162)}{11}$ $l = 0.0802$
EUR $l = \frac{(5.0677+0)-(4.4479-0)}{11}$ $l = \frac{(5.0677)-(4.4479)}{11}$ $l = 0.0563$	AUD $l = \frac{(3.2239+0)-(2.4487-0)}{11}$ $l = \frac{(3.2239)-(2.4487)}{11}$ $l = 0.0705$

Step 3: By referring to the value of l the result for grouping up the intervals were tabulated in tables 3.3 to 3.6 for USD, GBP, EUR, and AUD.

Table 3.3: Fuzzy Sets Intervals Table for United States Dollar (USD)

A_1	3.9965 - 4.0386
A_2	4.0386 - 4.0808
A_3	4.0808 - 4.1229
A_4	4.1229 - 4.1650
A_5	4.1650 - 4.2072
A_6	4.2072 - 4.2493
A_7	4.2493 - 4.2915
A_8	4.2915 - 4.3336
A_9	4.3336 - 4.3757
A_{10}	4.3757 - 4.4179
A_{11}	4.4179 - 4.4600

Table 3.4: Fuzzy Sets Intervals Table for British Pound Sterling (GBP)

A_1	5.0162 - 5.0964
A_2	5.0964 - 5.1766
A_3	5.1766 - 5.2568
A_4	5.2568 - 5.3370
A_5	5.3370 - 5.4172
A_6	5.4172 - 5.4974
A_7	5.4974 - 5.5776
A_8	5.5776 - 5.6578
A_9	5.6578 - 5.7380
A_{10}	5.7380 - 5.8182
A_{11}	5.8182 - 5.8984

Table 3.5: Fuzzy Sets Intervals Table for Euro (EUR)

A_1	4.4479	-	4.5042
A_2	4.5042	-	4.5606
A_3	4.5606	-	4.6169
A_4	4.6169	-	4.6733
A_5	4.6733	-	4.7296
A_6	4.7296	-	4.7860
A_7	4.7860	-	4.8423
A_8	4.8423	-	4.8987
A_9	4.8987	-	4.9550
A_{10}	4.9550	-	5.0114
A_{11}	5.0114	-	5.0677

Table 3.6: Fuzzy Sets Intervals Table for Australian Dollar (AUD)

A_1	2.4487	-	2.5192
A_2	2.5192	-	2.5896
A_3	2.5896	-	2.6601
A_4	2.6601	-	2.7306
A_5	2.7306	-	2.8011
A_6	2.8011	-	2.8715
A_7	2.8715	-	2.9420
A_8	2.9420	-	3.0125
A_9	3.0125	-	3.0830
A_{10}	3.0830	-	3.1534
A_{11}	3.1534	-	3.2239

Step 4: The fuzzified exchange rate is matched with its equivalent fuzzy sets. The result is shown below. Fuzzy Logical Relationships (FLRs) need to be established and grouped (FLRS) based on the current states of the data of the fuzzy logical relationships.

For example, $A_i \to A_{11}, A_i \to A_{12}, \dots, A_i \to A_{lp}$ where $l_1, l_2, \dots, l_p \in \{1,2,\dots,k\}$, group them as $A_i \to A_{11}, A_{12}, \dots, A_{lp}$. Suppose to have each fuzzy relationship's occurrences as $c_1, c_2, \dots, c_p$. By that, Fuzzy Logical Relationship will be defined and tabulated in table 3.7, 3.10, 3.13, and 3.16.

Table 3.7: Fuzzification and Fuzzy Logical Relationship for United States Dollar (USD)

Date	Price (USD)	Fuzzification	FLR		
1 July 2019	4.1335	A_4	NA	>	A_4
2 July 2019	4.1420	A_4	A_4	>	A_4
3 July 2019	4.1405	A_4	A_4	>	A_4
…	…	…	…	…	…
27 Dec 2019	4.1315	A_4	A_4	>	A_4
30 Dec 2019	4.1135	A_3	A_4	>	A_3
31 Dec 2019	4.0925	A_3	A_3	>	A_3
2 Jan 2020	4.0865	A_3	A_3	>	A_3
3 Jan 2020	4.0995	A_3	A_3	>	A_3
6 Jan 2020	4.1080	A_3	A_3	>	A_3
…	…	…	…	…	…
29 Dec 2020	4.0510	A_2	A_2	>	A_2
30 Dec 2020	4.0400	A_2	A_2	>	A_2
31 Dec 2020	4.0130	A_1	A_2	>	A_1
4 Jan 2021	3.9965	A_1	A_1	>	A_1
5 Jan 2021	4.0065	A_1	A_1	>	A_1
		A_1	A_1		A_1

6 Jan 2021	4.0145	…	…	>	…
…	…	A_5	A_5	…	A_5
29 Dec 2021	4.1815	A_5	A_5	>	A_5
30 Dec 2021	4.1705	A_5	A_5	>	A_5
31 Dec 2021	4.1760			>	
3 Jan 2022	4.1710	A_5	A_5	>	A_5
4 Jan 2022	4.1815	A_5	A_5	>	A_5
5 Jan 2022	4.1760	A_5	A_5	>	A_5
…	…	…	…	…	…
27 July 2022	4.4600	A_{11}	A_{11}	>	A_{11}
28 July 2022	4.4550	A_{11}	A_{11}	>	A_{11}
29 July 2022	4.4485	A_{11}	A_{11}	>	A_{11}

Table 3.8: Table for Fuzzy Logical Relationship Group for United States Dollar (USD)

A_1	A_1, A_2
A_2	A_1, A_2, A_3
A_3	A_2, A_3, A_4
A_4	A_3, A_4, A_5
A_5	A_4, A_5, A_6
A_6	A_5, A_6, A_7
A_7	A_6, A_7, A_8, A_9
A_8	A_7, A_8, A_9, A_{10}
A_9	A_7, A_8, A_9, A_{10}
A_{10}	A_9, A_{10}, A_{11}
A_{11}	A_{10}, A_{11}

Table 3.9: Fuzzy Relationship Frequency Table for United States Dollar (USD)

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	Total
A_1	8	5	0	0	0	0	0	0	0	0	0	13
A_2	5	56	3	0	0	0	0	0	0	0	0	64
A_3	0	3	60	11	0	0	0	0	0	0	0	74
A_4	0	0	11	153	11	0	0	0	0	0	0	175
A_5	0	0	0	12	169	8	0	0	0	0	0	189
A_6	0	0	0	0	9	74	1	0	0	0	0	84
A_7	0	0	0	0	0	2	38	1	1	0	0	42
A_8	0	0	0	0	0	0	2	9	5	0	0	16
A_9	0	0	0	0	0	0	1	5	27	4	0	37
A_{10}	0	0	0	0	0	0	0	1	4	37	2	44
A_{11}	0	0	0	0	0	0	0	0	0	3	18	21

Table 3.10: Fuzzification and Fuzzy Logical Relationship for British Pound Sterling (GBP)

Date	Price (GBP)	Fuzzification	FLR		
1 July 2019	5.2491	A_3	NA	>	A_3
2 July 2019	5.2347	A_3	A_3	>	A_3
3 July 2019	5.2133	A_3	A_3	>	A_3
…	…	…	…	…	…
27 Dec 2019	5.3707	A_5	A_5	>	A_5
30 Dec 2019	5.3957	A_5	A_5	>	A_5
31 Dec 2019	5.3722	A_5	A_5	>	A_5
2 Jan 2020	5.3983	A_5	A_5	>	A_5
3 Jan 2020	5.3853	A_5	A_5	>	A_5

6 Jan 2020	5.3743	A_5	A_5	$>$	A_5
...	...	...	...	$\cdots$	...
29 Dec 2020	5.4660	A_6	A_7	$>$	A_6
30 Dec 2020	5.4694	A_6	A_6	$>$	A_6
31 Dec 2020	5.4653	A_6	A_6	$>$	A_6
4 Jan 2021	5.4736	A_6	A_6	$>$	A_6
5 Jan 2021	5.4430	A_6	A_6	$>$	A_6
6 Jan 2021	5.4601	A_6	A_6	$>$	A_6
...	...	...	...	$\cdots$	...
29 Dec 2021	5.6173	A_8	A_8	$>$	A_8
30 Dec 2021	5.6248	A_8	A_8	$>$	A_8
31 Dec 2021	5.6361	A_8	A_8	$>$	A_8
3 Jan 2022	5.6306	A_8	A_8	$>$	A_8
4 Jan 2022	5.6302	A_8	A_8	$>$	A_8
5 Jan 2022	5.6710	A_9	A_8	$>$	A_9
...	...	...	...	$\cdots$	...
27 July 2022	5.3743	A_5	A_5	$>$	A_5
28 July 2022	5.4193	A_6	A_5	$>$	A_6
29 July 2022	5.4234	A_6	A_6	$>$	A_6

Table 3.11: Table for Fuzzy Logical Relationship Group for British Pound Sterling (GBP)

A_1	A_1, A_2, A_4
A_2	A_1, A_2, A_3
A_3	A_2, A_3
A_4	A_3, A_4, A_5
A_5	A_3, A_4, A_5, A_6

A_6	A_5, A_6, A_7
A_7	A_6, A_7, A_8
A_8	A_6, A_7, A_8, A_9
A_9	A_8, A_9, A_{10}
A_{10}	A_9, A_{10}, A_{11}
A_{11}	A_{10}, A_{11}

3.12: Fuzzy Relationship Frequency Table for British Pound Sterling (GBP)

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	Total
A_1	13	3	0	1	0	0	0	0	0	0	0	17
A_2	3	33	4	0	0	0	0	0	0	0	0	41
A_3	0	5	13	0	0	0	0	0	0	0	0	18
A_4	1	0	1	45	17	0	0	0	0	0	0	63
A_5	0	0	1	17	131	16	0	0	0	0	0	165
A_6	0	0	0	0	17	80	13	0	0	0	0	110
A_7	0	0	0	0	0	12	60	8	0	0	0	80
A_8	0	0	0	0	0	1	7	56	6	0	0	70
A_9	0	0	0	0	0	0	0	6	94	10	0	110
A_{10}	0	0	0	0	0	0	0	0	10	35	4	49
A_{11}	0	0	0	0	0	0	0	0	0	4	32	36

Table 3.13: Fuzzification and Fuzzy Logical Relationship for Euro (EUR)

Date	Price (EUR)	Fuzzification	FLR		
1 July 2019	4.6928	A_5	NA	>	A_5

2 July 2019	4.6722	A_4	A_5	$>$	A_4
3 July 2019	4.6734	A_5	A_4	$>$	A_5
…	…	…	…	…	…
27 Dec 2019	4.5938	A_3	A_3	$>$	A_3
30 Dec 2019	4.6069	A_3	A_3	$>$	A_3
31 Dec 2019	4.5852	A_3	A_3	$>$	A_3
2 Jan 2020	4.5824	A_3	A_3	$>$	A_3
3 Jan 2020	4.5800	A_3	A_3	$>$	A_3
6 Jan 2020	4.5870	A_3	A_3	$>$	A_3
…	…	…	…	…	…
29 Dec 2020	4.9590	A_{10}	A_9	$>$	A_{10}
30 Dec 2020	4.9623	A_{10}	A_{10}	$>$	A_{10}
31 Dec 2020	4.9324	A_9	A_{10}	$>$	A_9
4 Jan 2021	4.8971	A_8	A_9	$>$	A_8
5 Jan 2021	4.9174	A_9	A_8	$>$	A_9
6 Jan 2021	4.9322	A_9	A_9	$>$	A_9
…	…	…	…	…	…
29 Dec 2021	4.7278	A_5	A_6	$>$	A_5
30 Dec 2021	4.7283	A_5	A_5	$>$	A_5
31 Dec 2021	4.7256	A_5	A_5	$>$	A_5
3 Jan 2022	4.7335	A_6	A_5	$>$	A_6
4 Jan 2022	4.7241	A_5	A_6	$>$	A_5
5 Jan 2022	4.7336	A_6	A_5	$>$	A_6
…	…	…	…	…	…
27 July 2022	4.5236	A_2	A_2	$>$	A_2
28 July 2022	4.5486	A_2	A_2	$>$	A_2
29 July 2022	4.5433	A_2	A_2	$>$	A_2

Table 3.14: Table for Fuzzy Logical Relationship Group Euro (EUR)

A_1	A_1, A_2
A_2	A_1, A_2, A_3
A_3	A_2, A_3, A_4
A_4	A_3, A_4, A_5
A_5	A_4, A_5, A_6, A_7
A_6	A_5, A_6, A_7
A_7	A_5, A_6, A_7, A_8
A_8	A_7, A_8, A_9
A_9	A_8, A_9, A_{10}
A_{10}	A_9, A_{10}, A_{11}
A_{11}	A_{10}, A_{11}

Table 3.15: Fuzzy Relationship Frequency Table for Euro (EUR)

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	Total
A_1	12	4	0	0	0	0	0	0	0	0	0	16
A_2	4	25	4	0	0	0	0	0	0	0	0	33
A_3	0	3	82	18	0	0	0	0	0	0	0	103
A_4	0	0	17	66	11	0	0	0	0	0	0	94
A_5	0	0	0	10	39	12	2	0	0	0	0	63
A_6	0	0	0	0	11	61	9	0	0	0	0	81
A_7	0	0	0	0	3	8	50	6	0	0	0	67
A_8	0	0	0	0	0	0	6	70	17	0	0	93
A_9	0	0	0	0	0	0	0	17	98	15	0	130

A_{10}	0	0	0	0	0	0	0	0	15	40	4	59
A_{11}	0	0	0	0	0	0	0	0	0	4	16	20

Table 3.16: Fuzzification and Fuzzy Logical Relationship for Australian Dollar (AUD)

Date	Price (AUD)	Fuzzification	FLR		
1 July 2019	2.8945	A_7	NA	>	A_7
2 July 2019	2.8890	A_7	A_7	>	A_7
3 July 2019	2.8973	A_7	A_7	>	A_7
…	…	…	…	…	…
27 Dec 2019	2.8735	A_7	A_6	>	A_7
30 Dec 2019	2.8749	A_7	A_7	>	A_7
31 Dec 2019	2.8660	A_6	A_7	>	A_6
2 Jan 2020	2.8632	A_6	A_6	>	A_6
3 Jan 2020	2.8565	A_6	A_6	>	A_6
6 Jan 2020	2.8518	A_6	A_6	>	A_6
…	…	…	…	…	…
29 Dec 2020	3.0780	A_9	A_{10}	>	A_9
30 Dec 2020	3.0884	A_{10}	A_9	>	A_{10}
31 Dec 2020	3.0896	A_{10}	A_{10}	>	A_{10}
4 Jan 2021	3.0841	A_{10}	A_{10}	>	A_{10}
5 Jan 2021	3.0846	A_{10}	A_{10}	>	A_{10}
6 Jan 2021	3.1108	A_{10}	A_{10}	>	A_{10}
…	…	…	…	…	…
29 Dec 2021	3.0241	A_9	A_9	>	A_9
30 Dec 2021	3.0267	A_9	A_9	>	A_9
31 Dec 2021	3.0289	A_9	A_9	>	A_9
3 Jan 2022	3.0233	A_9	A_9	>	A_9

4 Jan 2022	3.0119	A_8	A_9	>	A_8
5 Jan 2022	3.0318	A_9	A_8	>	A_9
…	…	…	…	…	…
27 July 2022	3.0870	A_{10}	A_{10}	>	A_{10}
28 July 2022	3.1165	A_{10}	A_{10}	>	A_{10}
29 July 2022	3.1175	A_{10}	A_{10}	>	A_{10}

Table 3.17: Table for Fuzzy Logical Relationship Group for Australian Dollar (AUD)

A_1	A_3
A_2	A_1, A_2, A_3
A_3	A_2, A_3, A_4
A_4	A_3, A_5
A_5	A_4, A_5, A_6
A_6	A_5, A_6, A_7
A_7	A_6, A_7, A_8
A_8	A_7, A_8, A_9
A_9	A_8, A_9, A_{10}
A_{10}	A_9, A_{10}, A_{11}
A_{11}	A_{10}, A_{11}

Table 3.18: Fuzzy Relationship Frequency Table for Australian Dollar (AUD)

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	Total
A_1	0	0	1	0	0	0	0	0	0	0	0	1
A_2	1	1	1	0	0	0	0	0	0	0	0	3
A_3	0	2	7	3	0	0	0	0	0	0	0	12

A_4	0	0	3	0	1	0	0	0	0	0	0	4
A_5	0	0	0	1	50	3	0	0	0	0	0	54
A_6	0	0	0	0	3	117	5	0	0	0	0	125
A_7	0	0	0	0	0	5	32	8	0	0	0	45
A_8	0	0	0	0	0	0	9	92	18	0	0	119
A_9	0	0	0	0	0	0	0	19	143	10	0	172
A_{10}	0	0	0	0	0	0	0	0	11	111	13	135
A_{11}	0	0	0	0	0	0	0	0	0	13	76	89

Step 5: The weighting matrix is calculated as follows:

$$W(t) = [\frac{c_1}{\sum_{q=1}^{p} c_q}, \frac{c_2}{\sum_{q=1}^{p} c_q}, \dots, \frac{c_p}{\sum_{q=1}^{p} c_q}]$$

Assign weight matrix is shown in Table 3.19 to 3.22.

Table 3.19: Weight Matrix for USD (United States Dollar)

Weight matrix	$A_{1,1}$	$A_{1,2}$	$A_{1,3}$	…	$A_{11,11}$
Weight	$\frac{8}{13}$	$\frac{5}{13}$	$\frac{0}{13}$	…	$\frac{18}{21}$

Table 3.20: Weight Matrix for GBP (British Pound Sterling)

Weight matrix	$A_{1,1}$	$A_{1,2}$	$A_{1,3}$	…	$A_{11,11}$
Weight	$\frac{13}{17}$	$\frac{4}{17}$	$\frac{0}{17}$	…	$\frac{32}{36}$

Table 3.21: Weight Matrix for EUR (Euro)

Weight matrix	$A_{1,1}$	$A_{1,2}$	$A_{1,3}$	…	$A_{11,11}$

Weight	$\frac{12}{16}$	$\frac{4}{16}$	$\frac{0}{16}$	…	$\frac{16}{20}$

Table 3.22: Weight Matrix for AUD (Australian Dollar)

Weight matrix	$A_{1,1}$	$A_{1,2}$	$A_{1,3}$	…	$A_{11,11}$
Weight	$\frac{0}{1}$	$\frac{0}{1}$	$\frac{1}{1}$	…	$\frac{76}{89}$

A defuzzied matrix as a baseline for forecasting the daily price of the exchange rate of Ringgit Malaysia (RM) with United States Dollar (USD), British Pound Sterling (GDP), Euro (EUR), and Australian Dollar (AUD) for the next period is:

$$B_{dt}(t) = [m_{11}, m_{12}, \dots, m_{1p}]$$

where m_1 denotes the middle value of the interval A_1

Table 3.23: The midpoint for The Interval for United States Dollar (USD)

M_1	4.01757
M_2	4.05970
M_3	4.10184
M_4	4.14398
M_5	4.18611
M_6	4.22829
M_7	4.27039
M_8	4.31251
M_9	4.35466
M_{10}	4.39680
M_{11}	4.43893

Table 3.24: The midpoint for The Interval for British Pound Sterling (GBP)

M_1	5.05630
M_2	5.13650
M_3	5.21670
M_4	5.29690
M_5	5.37710
M_6	5.45730
M_7	5.53750
M_8	5.61770
M_9	5.69790
M_{10}	5.77810
M_{11}	5.85830

Table 3.25: The midpoint for The Interval for Euro (EUR)

M_1	4.47607
M_2	4.53242
M_3	4.58876
M_4	4.64511
M_5	4.70145
M_6	4.75780
M_7	4.81415
M_8	4.87049
M_9	4.92684

M_{10}	4.98318
M_{11}	5.03953

Table 3.26: The midpoint for The Interval for Australian Dollar (AUD)

M_1	2.48394
M_2	2.55441
M_3	2.62488
M_4	2.69535
M_5	2.76583
M_6	2.83630
M_7	2.90677
M_8	2.97725
M_9	3.04772
M_{10}	3.11819
M_{11}	3.18866

Forecasting value with weighting matrix in step 3 and defuzzied matrix according to

$$F(t+1) = B_{df}(t) \times W^T(t)$$

Table 3.27: The defuzzied matrix for each interval for United States Dollar (USD)

USD	$B_{df}(t)$	$W^T(t)$	$B_{df}(t) \times W^T(t)$
A_1	0 4.01757 4.05970	0 0.61538 0.38462	0 2.47235 1.56142 **4.03377**
A_2	4.01757 4.05970	0.07813 0.87500	0.31387 3.55224

	4.10184	0.04688	0.19227 **4.05839**
A_3	4.05970 4.10184 4.14398	0.04054 0.81081 0.14865	0.16458 3.32582 0.61600 **4.10640**
A_4	4.10184 4.14398 4.18611	0.06286 0.87429 0.06286	0.25783 3.62302 0.26313 **4.14398**
A_5	4.14398 4.18611 4.22825	0.06349 0.89418 0.04233	0.26311 3.74314 0.17897 **4.18522**
A_6	4.18611 4.22825 4.27039	0.10714 0.88095 0.01190	0.44851 3.72489 0.05084 **4.22424**
A_7	4.22825 4.27039 4.31252 4.35466	0.04762 0.90476 0.02381 0.02381	0.20135 3.86368 0.10268 0.10368 **4.27139**
A_8	4.27039 4.31252 4.35466	0.12500 0.56250 0.31250	0.53380 2.42579 1.36083 **4.32042**
A_9	4.27039 4.31252 4.35466 4.39680	0.02703 0.13514 0.72973 0.10811	0.11592 0.58277 3.17772 0.47533 **4.35124**
A_{10}	4.31252 4.35466 4.39680 4.43893	0.02273 0.09091 0.84091 0.04545	0.09801 0.39588 3.69731 0.20177 **4.39296**
A_{11}	4.39680 4.43893 0	0.14286 0.85714 0	0.62811 3.80480 0 **4.43201**

Table 3.28: The defuzzied matrix for each interval for British Pound Sterling (GBP)

GBP	$B_{df}(t)$	$W^T(t)$	$B_{df}(t) \times W^T(t)$
A_1	5.05630 5.13650 5.29690	0.76471 0.17647 0.05882	3.86658 0.90644 0.31158 **5.08461**
A_2	5.05630 5.13650 5.21670	0.09756 0.80488 0.09756	0.49330 4.13426 0.50895 **5.13650**

A_3	5.13650 5.21670 5.29690	0.08889 0.73333 0	1.42681 3.76762 0 **5.19442**
A_4	5.21670 5.29690 5.37710	0.01587 0.71429 0.26984	0.08280 3.78350 1.45096 **5.31727**
A_5	5.21670 5.29690 5.37710 5.45730	0.00606 0.10303 0.79394 0.09697	0.03162 0.54574 4.26909 0.52919 **5.37564**
A_6	5.37710 5.45730 5.53750	0.15455 0.72727 0.11818	0.83101 3.96895 0.65443 **5.37564**
A_7	5.45730 5.53750 5.61770	0.15000 0.75000 0.10000	0.81860 4.15313 0.56177 **5.53349**
A_8	5.45730 5.53750 5.61770 5.69790	0.01420 0.10000 0.80000 0.08571	0.07796 0.55375 4.49416 0.48839 **5.61426**
A_9	5.61770 5.69790 5.77810	0.05455 0.85455 0.09091	0.30642 4.86911 0.52528 **5.70082**
A_{10}	5.69790 5.77810 5.85830	0.20408 0.71429 0.08163	1.16284 4.12721 0.47823 **5.76828**
A_{11}	5.77810 5.85830 0	0.11111 0.88889 0	0.64201 5.20738 0 **5.84939**

Table 3.29: The defuzzied matrix for each interval for Euro (EUR)

EUR	$B_{df}(t)$	$W^T(t)$	$B_{df}(t) \times W^T(t)$
A_1	0 4.47607 4.53242	0 0.75000 0.25000	0 3.35705 1.13310 **4.49016**
A_2	4.47607 4.53242 4.58876	0.12121 0.75758 0.12121	0.54255 3.43365 0.55621 **4.53242**
A_3	4.53242 4.58876 4.64511	0.02913 0.79612 0.17476	0.13201 3.65319 0.81177

			4.59697
A_4	4.58876 4.64511 4.70145	0.18085 0.70213 0.11702	0.82988 3.26146 0.55017 **4.64151**
A_5	4.64511 4.70145 4.75780 4.81415	0.15873 0.61905 0.19048 0.03175	0.73732 2.91042 0.90625 0.15283 **4.70682**
A_6	4.70145 4.75780 4.81415	0.13580 0.75309 0.11111	0.63847 3.58303 0.53491 **4.75641**
A_7	4.70145 4.75780 4.81415 4.87049	0.04478 0.11940 0.74627 0.08925	0.21051 0.56810 3.59265 0.43616 **4.80742**
A_8	4.81415 4.87049 4.92684	0.06452 0.75269 0.18280	0.31059 3.66596 0.90060 **4.87716**
A_9	4.87049 4.92684 4.98318	0.13077 0.75385 0.11538	0.63691 3.71408 0.57498 **4.92597**
A_{10}	4.92684 4.98318 5.03953	0.25424 0.67797 0.06780	1.25259 3.37843 0.34166 **4.97268**
A_{11}	4.98318 5.03953 0	0.20000 0.80000 0	0.99664 4.03162 0 **5.02826**

Table 3.30: The defuzzied matrix for each interval for Australian Dollar (AUD)

AUD	$B_{df}(t)$	$W^T(t)$	$B_{df}(t) \times W^T(t)$
A_1	2.48394 2.55441 2.62488	0 0 1	0 0 2.62488 **2.62488**
A_2	2.48394 2.55441 2.62488	0.33333 0.33333 0.33333	0.82798 0.85147 0.87496 **2.55441**
A_3	2.55441 2.62488 2.69535	0.16667 0.58333 0.25000	0.42573 1.53118 0.67384 **2.63075**
A_4	2.62488 2.69535	0.75000 0	1.96866 0

	2.76583	0.25000	0.69146 **2.66012**
A_5	2.69535 2.76583 2.83630	0.01852 0.92593 0.05556	0.04991 2.56095 0.15757 **2.76844**
A_6	2.76583 2.83630 2.90677	0.02400 0.93600 0.04000	0.06638 2.65478 0.11627 **2.83743**
A_7	2.83630 2.90677 2.97725	0.11111 0.71111 0.17778	0.31514 2.06704 0.52929 **2.91147**
A_8	2.90677 2.97725 3.04772	0.07563 0.77311 0.15126	0.21984 2.30174 0.46100 **2.98258**
A_9	2.97725 3.04772 3.11819	0.11047 0.83140 0.05814	0.32888 2.53386 0.18129 **3.04403**
A_{10}	3.04772 3.11819 3.18866	0.08148 0.82222 0.09630	0.24833 2.56385 0.30706 **3.11923**
A_{11}	3.11819 3.18866 0	0.14607 0.85393 0	0.45547 2.72290 0 **3.17837**

Step 6: The forecast error is calculated to find the forecast value.

Forecast error can be found by minus the defuzzied value and daily price of the exchange rate.

Table 3.31 to 3.34 below shows the defuzzied value and forecast error of the United States Dollar (USD), British Pound Sterling (GBP), Euro (EUR), and Australian Dollar (AUD).

Table 3.31: The Forecast Error for United States Dollar (USD)

Date	Price (USD)	Defuzzied value	Forecast error
1 July 2019	4.1335	4.14398	0
2 July 2019	4.1420	4.14398	-0.00198
3 July 2019	4.1405	4.14398	-0.00348
…	…	…	…
27 Dec 2019	4.1315	4.14398	-0.01248
30 Dec 2019	4.1135	4.10184	-0.03048
31 Dec 2019	4.0925	4.10184	-0.00934
2 Jan 2020	4.0865	4.10184	-0.01534
3 Jan 2020	4.0995	4.10184	-0.00234
6 Jan 2020	4.1080	4.10184	0.00616
…	…	…	…
29 Dec 2020	4.0510	4.05970	-0.00870

30 Dec 2020	4.0400	4.05970	-0.01970
31 Dec 2020	4.0130	4.03864	-0.04670
4 Jan 2021	3.9965	4.03864	-0.04214
5 Jan 2021	4.0065	4.03864	-0.03214
6 Jan 2021	4.0145	4.03864	-0.02414
…	…	…	…
29 Dec 2021	4.1815	4.18611	-0.00461
30 Dec 2021	4.1705	4.18611	-0.01561
31 Dec 2021	4.1760	4.18611	-0.01011
3 Jan 2022	4.1710	4.18611	-0.01511
4 Jan 2022	4.1815	4.18611	-0.00461
5 Jan 2022	4.1760	4.18611	0.00439
…	…	…	…
27 July 2022	4.4600	4.41786	0.04214
28 July 2022	4.4550	4.41786	0.03714
29 July 2022	4.4485	4.41786	0.03064

Table 3.32: The Forecast Error for British Pound Sterling (GBP)

Date	Price (GBP)	Defuzzied value	Forecast error
1 July 2019	5.2491	5.1766	0
2 July 2019	5.2347	5.1766	0.0581
3 July 2019	5.2133	5.1766	0.0367
…	…	…	…
27 Dec 2019	5.3707	5.3370	0.0337
30 Dec 2019	5.3957	5.3370	0.0587
31 Dec 2019	5.3722	5.3370	0.0352
2 Jan 2020	5.3983	5.3370	0.0613
3 Jan 2020	5.3853	5.3370	0.0483
6 Jan 2020	5.3743	5.3370	0.0373
…	…	…	…
29 Dec 2020	5.4660	5.4573	-0.0715
30 Dec 2020	5.4694	5.4573	0.0121
31 Dec 2020	5.4653	5.4573	0.0080
4 Jan 2021	5.4736	5.4573	0.0163
5 Jan 2021	5.4430	5.4573	-0.0143
6 Jan 2021	5.4601	5.4573	0.0028
…	…	…	…
29 Dec 2021	5.6172	5.5776	0.0396
30 Dec 2021	5.6248	5.5776	0.0472
31 Dec 2021	5.6361	5.5776	0.0585
3 Jan 2022	5.6306	5.5776	0.0530
4 Jan 2022	5.6302	5.5776	0.0526
5 Jan 2022	5.6710	5.6979	0.0934
…	…	…	…
27 July 2022	5.3743	5.3378	0.0373
28 July 2022	5.4193	5.4573	0.0823
29 July 2022	5.4234	5.4573	-0.0339

Table 3.33: The Forecast Error for Euro (EUR)

Date	Price (EUR)	Defuzzied value	Forecast error
1 July 2019	4.6928	4.7296	0

2 July 2019	4.6722	4.6451	-0.0574
3 July 2019	4.6734	4.6451	0.0283
…	…	…	…
27 Dec 2019	4.5938	4.5888	0.0050
30 Dec 2019	4.6069	4.5888	0.0181
31 Dec 2019	4.5852	4.5888	-0.0036
2 Jan 2020	4.5824	4.5888	-0.0064
3 Jan 2020	4.5800	4.5888	-0.0088
6 Jan 2020	4.5870	4.5888	-0.0018
…	…	…	…
29 Dec 2020	4.9590	4.9832	0.0322
30 Dec 2020	4.9623	4.9832	-0.0209
31 Dec 2020	4.9324	4.9268	-0.0508
4 Jan 2021	4.8971	4.8705	-0.0297
5 Jan 2021	4.9174	4.9268	0.0469
6 Jan 2021	4.9322	4.9268	0.0054
…	…	…	…
29 Dec 2021	4.7278	4.7296	-0.0300
30 Dec 2021	4.7283	4.7296	-0.0013
31 Dec 2021	4.7256	4.7296	-0.0040
3 Jan 2022	4.7335	4.7578	0.0039
4 Jan 2022	4.7241	4.7296	-0.0337
5 Jan 2022	4.7336	4.7578	0.0040
…	…	…	…
27 July 2022	4.5236	4.5324	-0.0088
28 July 2022	4.5486	4.5324	0.0162
29 July 2022	4.5433	4.5324	0.0109

Table 3.34: The Forecast Error for Australian Dollar (AUD)

Date	Price (AUD)	Defuzzied value	Forecast error
1 July 2019	2.8945	2.9068	0
2 July 2019	2.8890	2.9068	-0.0178
3 July 2019	2.8973	2.9068	-0.0095
…	…	…	…
27 Dec 2019	2.8735	2.9068	0.0372
30 Dec 2019	2.8749	2.9068	-0.0319
31 Dec 2019	2.8660	2.8363	-0.0408
2 Jan 2020	2.8632	2.8363	0.0269
3 Jan 2020	2.8565	2.8363	0.0202
6 Jan 2020	2.8518	2.8363	0.0155
…	…	…	…
29 Dec 2020	3.0780	3.0477	-0.0402
30 Dec 2020	3.0884	3.1182	0.0407
31 Dec 2020	3.0896	3.1182	-0.0286
4 Jan 2021	3.0841	3.1182	-0.0341
5 Jan 2021	3.0846	3.1182	-0.0336
6 Jan 2021	3.1108	3.1182	-0.0074
…	…	…	…
29 Dec 2021	3.0241	3.0477	-0.0236
30 Dec 2021	3.0267	3.0477	-0.0210
31 Dec 2021	3.0289	3.0477	-0.0188
3 Jan 2022	3.0233	3.0477	-0.0244
4 Jan 2022	3.0119	2.9772	-0.0358
5 Jan 2022	3.0318	3.0477	0.0546
…	…	…	…
27 July 2022	3.0870	3.1182	-0.0312

28 July 2022	3.1165	3.1182	-0.0017
29 July 2022	3.1175	3.1182	-0.0007

Step 7: Using an adaptive forecasting model controls the forecast outcome because of the exchange rate daily price. This study simply uses one period error to update the forecast. Otherwise, a cumulative variance will produce a poor predicting result. If the current fuzzy price is P(t), the following period's price is calculated as follows:

$$F(t+1) = P(t) + \varepsilon_{t-1}$$

Where ε_{t-1} denotes forecasting errors of period $t-1$.

Table 3.35: The Forecast Result for United States Dollar (USD).

Date	Price	Forecast
1 July 2019	4.1335	0
2 July 2019	4.1420	4.1505
3 July 2019	4.1405	4.1457
…	…	…
27 Dec 2019	4.1315	4.1329
30 Dec 2019	4.1135	4.1206
31 Dec 2019	4.0925	4.0984
2 Jan 2020	4.0865	4.0820
3 Jan 2020	4.0995	4.0711
6 Jan 2020	4.1080	4.0864
…	…	…
29 Dec 2020	4.0510	4.0585
30 Dec 2020	4.0400	4.0471
31 Dec 2020	4.0130	4.0188
4 Jan 2021	3.9965	3.9986
5 Jan 2021	4.0065	3.9943
6 Jan 2021	4.0145	3.9946
…	…	…
29 Dec 2021	4.1815	4.1760
30 Dec 2021	4.1705	4.1689
31 Dec 2021	4.1760	4.1590
3 Jan 2022	4.1710	4.1630
4 Jan 2022	4.1815	4.1731
5 Jan 2022	4.1760	4.1820
…	…	…
27 July 2022	4.4600	4.4600
28 July 2022	4.4550	4.4550
29 July 2022	4.4485	4.4485

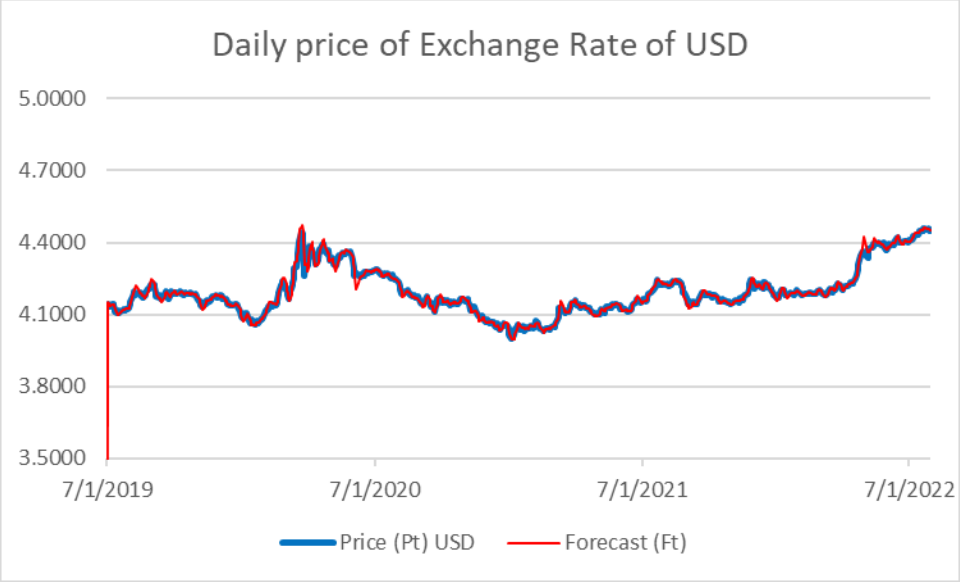

Figure 3.2: Line graph of the daily price of the Exchange rate of USD

Based on Figure 3.2, the graph shows the daily price of the Exchange rate of Malaysian Ringgit (MYR) with the United States Dollar (USD). The result shows the similarity between the actual price of USD and the daily price forecast. The highest actual price of USD is on 27 July 2022, which is 4.4600. The lowest actual price of USD was on 04 January 2021, which was 3.9965. It shows that the economy of Malaysia has been relatively stable for four years, from 2019 to 2022.

Table 3.36: The Forecast Result for British Pound Sterling (GBP)

Date	Price	Forecast
1 July 2019	5.2491	0
2 July 2019	5.2347	5.2203
3 July 2019	5.2133	5.1966
…	…	…
27 Dec 2019	5.3707	5.3419
30 Dec 2019	5.3957	5.3700
31 Dec 2019	5.3722	5.3747
2 Jan 2020	5.3983	5.3907
3 Jan 2020	5.3853	5.4012
6 Jan 2020	5.3743	5.3876
…	…	…
29 Dec 2020	5.4660	5.4875
30 Dec 2020	5.4694	5.4940
31 Dec 2020	5.4653	5.4864
4 Jan 2021	5.4736	5.4734
5 Jan 2021	5.4430	5.4479
6 Jan 2021	5.4601	5.4507
…	…	…
29 Dec 2021	5.6172	5.6328
30 Dec 2021	5.6248	5.6280
31 Dec 2021	5.6361	5.6287

3 Jan 2022	5.6306	5.6288
4 Jan 2022	5.6302	5.6356
5 Jan 2022	5.6710	5.6550
…	…	…
27 July 2022	5.3743	5.3749
28 July 2022	5.4193	5.3995
29 July 2022	5.4234	5.4481

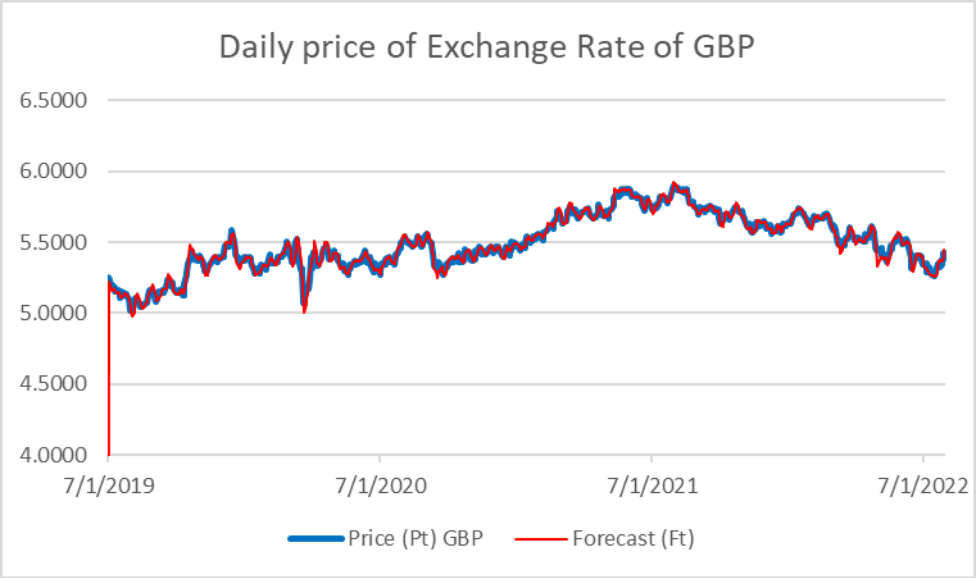

Figure 3.3: Line graph of the daily price of the Exchange rate of GBP

Based on Figure 3.3, the graph shows the daily price of the Exchange rate of the Malaysian Ringgit (MYR) with British Pound Sterling (GBP). The result shows the similarity between the actual GBP price and the daily price forecast. The highest actual price of GBP is on 30 July 2021, which is 5.8984, while the lowest actual price of GBP is on 31 July 2019, which is 5.0162. Based on the data, the level of Malaysia's economy was relatively stable in 2019 to 2022, but declined slightly in the middle of 2021.

Table 3.37: The Forecast Result for Euro (EUR)

Date	Price	Forecast
1 July 2019	4.6928	0
2 July 2019	4.6722	4.6516
3 July 2019	4.6734	4.6601
…	…	…
27 Dec 2019	4.5938	4.5797
30 Dec 2019	4.6069	4.5942
31 Dec 2019	4.5852	4.5915
2 Jan 2020	4.5824	4.5886
3 Jan 2020	4.5800	4.5817
6 Jan 2020	4.5870	4.5830
…	…	…
29 Dec 2020	4.9590	4.9588

30 Dec 2020	4.9623	4.9624
31 Dec 2020	4.9324	4.9447
4 Jan 2021	4.8971	4.9151
5 Jan 2021	4.9174	4.9073
6 Jan 2021	4.9322	4.9081
…	…	…
29 Dec 2021	4.7278	4.7309
30 Dec 2021	4.7283	4.7240
31 Dec 2021	4.7256	4.7049
3 Jan 2022	4.7335	4.7193
4 Jan 2022	4.7241	4.7241
5 Jan 2022	4.7336	4.7289
…	…	…
27 July 2022	4.5236	4.5454
28 July 2022	4.5486	4.5407
29 July 2022	4.5433	4.5418

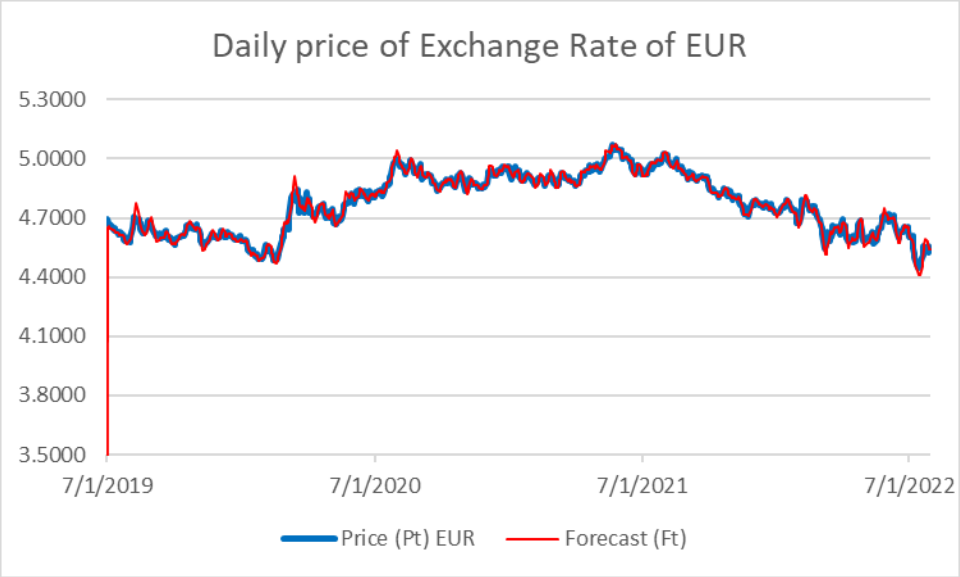

Figure 3.4: Line graph of the daily price of the Exchange rate of EUR

Based on Figure 3.4, the graph shows the daily price of the Exchange rate of Malaysian Ringgit (MYR) with Euro (EUR). The result shows the similarity between the actual price of EUR and the forecast of daily price. The highest actual price of EUR is on 21 Mei 2021, which is 5.0677. The lowest actual price of EUR is on 13 July 2022, which is 4.4479. Malaysia's economic level somewhat declined in 2020, which is the year of the pandemic Covid-19 and become stable in 2022.

Table 3.38: The Forecast Result for the Australian Dollar (AUD).

Date	Price	Forecast
1 July 2019	2.8945	0
2 July 2019	2.8890	2.8835
3 July 2019	2.8973	2.8964

…	…	…
27 Dec 2019	2.8735	2.8832
30 Dec 2019	2.8749	2.8795
31 Dec 2019	2.8660	2.8755
2 Jan 2020	2.8632	2.8689
3 Jan 2020	2.8565	2.8612
6 Jan 2020	2.8518	2.8530
…	…	…
29 Dec 2020	3.0780	2.0837
30 Dec 2020	3.0884	2.0895
31 Dec 2020	3.0896	2.0982
4 Jan 2021	3.0841	3.0909
5 Jan 2021	3.0846	3.0862
6 Jan 2021	3.1108	3.0977
…	…	…
29 Dec 2021	3.0241	3.0359
30 Dec 2021	3.0267	3.0306
31 Dec 2021	3.0289	3.0233
3 Jan 2022	3.0233	3.0213
4 Jan 2022	3.0119	3.0159
5 Jan 2022	3.0318	3.0224
…	…	…
27 July 2022	3.0870	3.0986
28 July 2022	3.1165	3.1073
29 July 2022	3.1175	3.1296

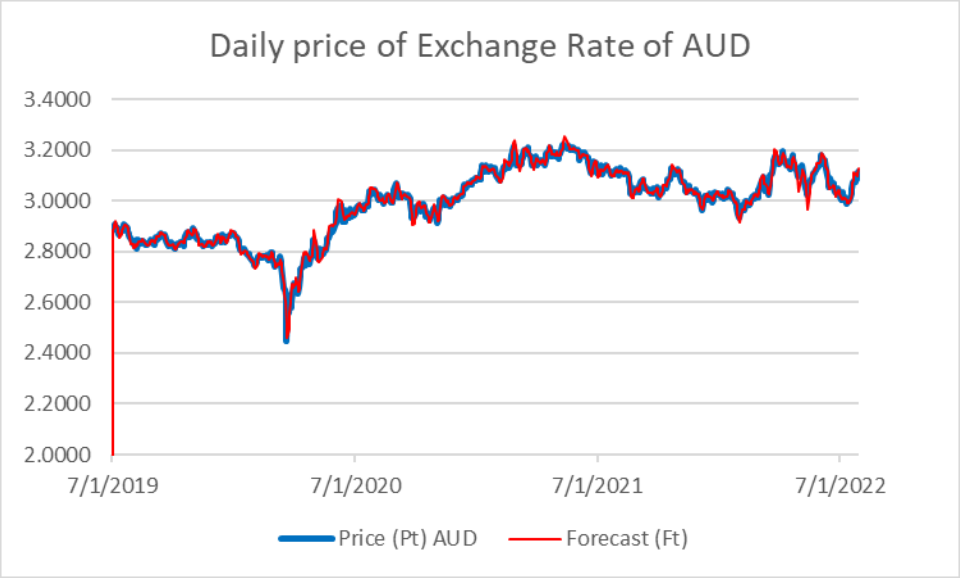

Figure 3.5: Line graph of the daily price of the Exchange rate of AUD

Based on Figure 3.5, the graph shows the daily price of the Exchange rate of Malaysian Ringgit (MYR) with the Australian Dollar (AUD). The result shows the similarity between the actual price of AUD and the forecast of daily price. The highest actual price of AUD is on 11 May 2021, which is 3.2239. The lowest actual price of AUD is on 19 March 2020, which is 2.4487. Economy of Malaysia was stable but start the middle of year of the 2020, the economy starts to be deteriorated.

3.3. Forecasting Result Evaluation

To check the accuracy of the prediction of the exchange rate by using the method, which is Fuzzy Time Series, Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE) are being used. The result of the RMSE and MAPE for this method are shown in Table 3.39.

Table 3.39: RMSE and MAPE for the Fuzzy Times Series

Method		Root Mean Square Error (RMSE)	Mean Absolute Percentage Error (MAPE)
Fuzzy Times Series	USD	0.0050	0.000158%
	GBP	0.0072	0.000173%
	EUR	0.0065	0.000180%
	AUD	0.0036	0.000158%

Based on Table 3.28, the result shows that the RMSE and MAPE for this method for USD, GBP, EUR, and AUD. The results show that Fuzzy Time Series produce a good forecast result because the analysis shows that Fuzzy Time Series have the lowest value of RMSE and MAPE which is below then one

4. Conclusion and Recommendation

This chapter will conclude the Fuzzy Time Series and Moving Average Method study to predict the currency exchange rate. There will be a few recommendations for future research related to this study.

This study analyses the method of forecasting the daily price of currency exchange rate using the Fuzzy Times Series. Malaysia's currency is the Malaysian Ringgit. According to our rankings, the MYR to USD conversion rate is the most often used Malaysian Ringgit exchange rate. Ringgits have the MYR currency code and the RM currency sign. The Malaysian Central Bank is responsible for issuing the ringgit. Based on the raw data of the exchange rate, Malaysia’s economy is quite slow when compared to other countries but still stable.

The analysis result of RMSE for USD, GBP, EUR, and AUD by using the Fuzzy Times Series are 0.0050, 0.0072, 0.0065, and 0.0036, respectively. Moreover, the analysis result of MAPE for USD, GBP, EUR, and AUD by using the Fuzzy Times Series are 0.000158%, 0.000173%, 0.000180%, and 0.000158%, respectively. Even though the value of MAPE for this method is below 1%, the result using the Fuzzy Times Series has the lowest value, which determines the best MAPE result. For further study, advanced software such as MATLAB, SAS, and MINITAB can be applied to the proposed model to simulate the result conveniently

and effectively. Besides, further exploration, such as using the data for the years of 2022, is needed to aim for better performance in exchange rate forecasting.

This study also explores the benefits of these two methods in the forecasting exchange rate. Government, investors, and communities are the three major parties that can benefit from this study. A stable currency might be crucial for the government for a nation to be able to borrow internationally without experiencing major problems with its foreign loans. A fixed, or at least stable, the exchange rate also benefits domestic monetary stability or low inflation. Exchange rates will have an impact on imports and exports, which will then have an impact on overall economic demand. Many businesses, but notably banks, may have problems because of exchange rate fluctuations. Changes in the currency rate may accompany unsustainable international financial capital flows.

Brokers and companies may use a forecast of the currency exchange rate to assist them in making wise decisions that will help them reduce risks and maximise rewards. There are several ways to predict currency exchange rates. Investors should take note of this as fluctuating exchange rates affect the value of imported items' pricing as well as local products that depend on imported components and raw materials. Exchange rates can also have an impact on the employment market and real estate market, in addition to having an impact on inflation, interest rates, and investment performance.

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