

# Autoregressive Integrated Moving Average Model with Exogenous Variable (ARIMAX) for Forecasting the Money Supply in Indonesia

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## Abstract

The autoregressive integrated moving average model with exogenous variables (ARIMAX) is an extension of the ARIMA model by adding one or more other time series data referred to as exogenous variables. Exogenous variables are added in the model to increase the accuracy of forecasting to be carried out. The ARIMAX model is used to predict data on the money supply in Indonesia, both narrow money supply and wide money circulation with the exchange rate as an exogenous variable. This study aims to obtain the best ARIMAX model and the results of forecasting the money supply in Indonesia using the exchange rate as an exogenous variable. The results of this study indicate that forecasting the narrow money supply in Indonesia for the period January 2014 to December 2021 with the ARIMAX(0,2,2) model is the best model with a MAPE value of 2.1829. Meanwhile, the results of forecasting the money supply in Indonesia for the period January 2014 to December 2021 with the ARIMAX(2,2,0) model is the best model with a MAPE value of 1.0323. The two models produced have insignificant exogenous values in the ARIMAX model so that the significant models are ARIMA(0,2,2) and ARIMA(2,2,0) models.

*Keywords:* Type your keywords here, between 3 and 6, separated by semicolons.

Received: 17 October 2025

Revised: 30 March 2026

Published: 30 April 2026

## 1. Introduction

Forecasting is an estimate or prediction of something that will happen in the future using both past and present data (Aswi & Sukarna, 2006). The inability to predict an event accurately and precisely makes forecasting important to do, by choosing the appropriate forecasting method and having a high level of accuracy and having a minimum error. One way to do forecasting is to use time series analysis (Box & Jenkins, 1976; Makridakis et al., 1998; Montgomery et al., 2015; Nurman & others, 2022).

One of the time series models that can be viewed as an extension of the ARIMA time series model is the Autoregressive Integrated Moving Average with Exogenous Variable (ARIMAX) model. ARIMAX is an ARIMA model that has exogenous variables (Laga & others, 2018). The function of ARIMAX is that it can handle analytical interventions and outliers in a time series. The ARIMAX model has several advantages which are able to consider the influence of observation values in a certain period, and can consider the influence of a number of exogenous variables on response variables (Andreas et al., 2021; Brockwell & Davis, 2002; Enders, 2014).

Forecasting accuracy can be improved by incorporating exogenous variables into the time series model (Hidayat & Hakim, 2021). Forecasting accuracy can be improved by incorporating exogenous variables into the time series model (Hidayat & Hakim, 2021; Wicaksono & others, 2023). One of the factors that affect the money supply in Indonesia is the rupiah exchange rate (Mankiw, 2014; Mishkin, 2015; Sukmana & Suryani, 2022). If the money supply is too much, the value of the rupiah decreases and if the money supply is too small, the government will reduce the amount of money in circulation, so that the value of the rupiah will increase (Harahap & others, 2019).

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Previous research using the ARIMAX model in forecasting Newton et al. (2020) also conducted research using the ARIMAX model in analyzing inflation with Google trends. So it was concluded that the best model is ARIMAX (2,0,3). The results of the ARIMAX forecast (2,0,3) of all X converters show quite good forecast results because the forecast results are almost the same as the original BPS data. In addition, Martha (2020) conducted time-lapse data modeling with ARIMAX which resulted in the conclusion that the arimax model estimate on AALI stock price data from the period January 2010 to December 2018 obtained the best model was ARIMAX (0,1,1). ARIMAX shows that variables have a significant effect on the share price of PT. Astra Agro Lestari Tbk is the share price itself while the USD rate is not significant in the model (0,1,1) so it shows that the USD rate does not have a significant effect on the stock price.

Thus, to find out whether the amount of money in circulation has an influence in forecasting using the ARIMAX model, the exogenous variable that will be used in this study is the rupiah exchange rate.

## 2. Literature Review

### 2.1. Forecasting

Forecasting is one of the integral parts of decision-making activities, because the effectiveness and ineffectiveness of a decision generally depends on several factors that cannot be seen at the time the decision is taken (Aswi & Sukarna, 2006). Forecasting is a way to reduce the level of risk that may occur and is one of the tools that makes the resulting decisions more appropriate and higher in validity weight (Box et al., 2008; Hyndman & Athanasopoulos, 2018; Sudaryono, 2021).

### 2.2. Time Series Analysis

Time series are an orderly sequence of observations. Although sorting can be through time, especially in some time intervals with equal distances, sorting can also be done through other dimensions, such as space (Gujarati & Porter, 2009; Tsay, 2005; Wei, 2006). Time series analysis is a sequence of observations based on the same time interval. The time used can be in the form of days, weeks, months, years, and so on in the context of making decisions as projections for the future (Vivianti et al., 2020).

### 2.3. Time Series Stationary and Non-Stationary

Time series are said to be stationary if there is no change in tendency in average and change in variance. In other words, a stationary time series is relatively no sharp increase or decrease in value in the data (data fluctuations are around a constant average value). In simple terms, the concept of stationary can be interpreted as a condition where the value of a data is not much different or may be the same as other data. In practice, this testing process can be carried out efficiently through the help of computer packages. Features in the formation of a time series analysis model are to assume that the data is in a stationary state (Aswi & Sukarna, 2006).

### 2.4. Data Time Series Data Stationary Check

The shape of a time series diagram can give an idea of whether or not a time series data is stationary, visually it can be seen from the trend (trend pattern) of the data (Aswi & Sukarna, 2006).

### 2.5. Autocorrelation Function (FAK) and Partial Autocorrelation Function (FAKP)

The autocorrelation coefficient (FAK) is a function that shows the magnitude of the correlation (linear relationship) between observations at the t-th time (annotated by  $Z_t$ ) with observation at the time  $Z_{t+k}$ . For  $Z_t$  the stationary has an average value  $E(Z_t) = \mu$  and variance  $Var(Z_t) = E(Z_t - \mu)^2 = \sigma^2$  which is constant. Meanwhile, the partial autocorrelation function (FAKP) is a function that shows the magnitude of the partial correlation between observations at the t-th time (annotated with  $Z_t$ ) and observations at previous times (Aswi & Sukarna, 2006).

## 2.6. General models of time series

There are several Time Series models that exist including, Autoregressive (AR) Model with equations  $\phi_p(B)Z_t = a_t$ , Moving Average (MA) model with equations  $\theta_q(B) = (1 - \theta_1 B - \theta_2 B^2 - \dots - \theta_q B^q)$ , then the Autoregressive Moving Average (ARMA) model which is a combination of the AR and MA models with equations  $\phi_p(B)Z_t = \theta_q(B)a_t$ , and The Autoregressive Integrated Moving Average (ARIMA) model which has an order (p,d,q), p is an order of AR, d represents a differencing, and q is an MA order (Aswi & Sukarna, 2006). In general, the form of the ARIMA model (p,d,q) is as follows:

$$\phi_p(B)(1 - B)^d Z_t = \theta_q(B)a_t \tag{1}$$

where:

- $\phi_p$  = coefficient of order p
- $\theta_q$  = coefficient of order q
- $(1 - B)^d$  = non-seasonal differencing order
- $Z_t$  = magnitude of observation (occurrence) at the t time
- $a_t$  = a process of white noise or error at the assumed t time has an average of 0 and a constant variance of  $\sigma_a^2$ .

## 2.7. Stages of The ARIMA Model

### (1). Model Identification

The initial stage for identifying a temporary model is to determine whether the time series data to be used for forecasting is stationary or not, both in average and in variance. This is important because these models only apply to stationary data (Aswi & Sukarna, 2006).

### (2). Parameter Estimation

After carrying out the identification process and obtaining a temporary model, the next step is to assess the parameters of the temporary model using the least squares method.

### (3). Diagnostic Examination

To find out a feasible model, it can be done by conducting a residual independence test and a residual normality test. The residual independence test can also be done with the Ljung-Box Test, which compares the p-value with alpha. While the residual normality test can be done by looking at the residual histogram produced by the model.

### (4). Forecasting

The forecasting stage can be carried out if all the parameters of the model are significant and all the remaining assumptions are met.

## 2.8. Model Autoregressive Integrated Moving Average With Exogenous Variable (ARIMAX)

One of the time series models that can be viewed as an extension of the ARIMA time series model is the Autoregressive Integrated Moving Average with Exogenous Variable (ARIMAX) model (Hendikawati, 2018; Susila, 2020). ARIMAX is an ARIMA model with the addition of free variables or exogenous variables that are considered to have an influence on other variables, but are not influenced by other variables in the model (Newing dkk., 2025; Saputri, 2025). Exogenous variables are commonly referred to as free variables. In doing forecasting, there are often exogenous variables that affect the model (Laga & others, 2018). One of the functions of ARIMAX is that it can handle the intention of analysis and outlier in a time series (Cryer & Chan, 2008b).

In doing forecasting, there are often exogenous variables that affect the model (Laga & others, 2018; Setiawan & Suhartono, 2019). One of the functions of ARIMAX is that it can handle the intention of analysis and outlier in a time series (Cryer & Chan, 2008). (Arianti dkk., 2022) say that the general form of the ARIMAX model equation (p,d,q) is as follows :

$$\phi_p(B)(1 - B)^d Z_t = \theta_q(B)a_t + e_1 x_{1,t} + \dots + e_k x_{k,t} \tag{2}$$

with:

$\phi_p(B)$  = Autoregressive Components  
 $\theta_q(B)$  = Moving Average Components  
 $Z_t$  = dependent variable  
 $B$  = backshift operator  
 $x_{k,t}$  = k-th exogenous variable when t, k : 1,2,...,n  
 $e$  = coefficient of the exogenous variable

### 2.9. Mean Absolute Percentage Error (MAPE)

Mean Absolute Percentage Error (MAPE) is used to calculate the average percentage of error or measure the accuracy of the forecasting carried out, the accuracy of forecasting can be seen from the MAPE results obtained. MAPE is said to be very good if the MAPE obtained is less than 10%, if the MAPE obtained is between 10% - 20% it can be said to be good forecasting, if forecasting is obtained 20% - 50% then forecasting is quite good, and if the MAPE is more than 50% then the forecasting is bad (Wijayanti dkk., 2021).

### 2.10. Money Supply

The money supply is defined into two, namely, the narrow money supply (M1) and the wide money supply (M2). M1 is money owned by the community in the form of quarterly money and giral money. While M2 is money owned by the community in the form of quarterly money, giral money and quasi-money (Rumondor et al., 2021). Currency is banknotes and coins used by the public to carry out daily transactions as legal tender. While giral money is a bill in a commercial bank, which can be used at any time as a means of payment, giral money consists of checking accounts, remittances, term deposits and rupiah savings that have fallen over time, all of which are residents' deposits in Rupiah. Quasi-money is a form of wealth that is considered quite liquid, in the near future it can be cashed out in banks. Some examples of quasi-money include time deposits, savings, and government bonds (Lestari, 2014).

### 2.11. JISDOR Rate

According to Bank Indonesia JISDOR (Jakarta Interbank Spot Dollar Rate) is a reference rate that presents the rupiah exchange rate against the United States dollar from interbank transactions in the foreign exchange market including transactions with banks abroad. JISDOR is obtained by calculating a wighted average based on the transaction volume of the rupiah exchange rate against the United States dollar in the spot market.

## 3. Research Method

### 3.1. Types of Research

The type of research used is quantitative research. Quantitative research is research whose analysis focuses more on data.

### 3.2. Data Sources

The data used in this study is secondary data obtained from the Bank Indonesia (BI) website processed by the data center and information system of the Ministry of Trade and JISDOR Exchange Rate data which can be accessed through the BI website page (bi.go.id).

### 3.3. Operational Definition of Variables

The variables used in this study are:

#### (1). Narrow money supply (Y1)

The narrow money supply (Y1) is the money supply consisting of currency (banknotes and coins) and current money (checking accounts, remittances, term deposits and rupiah savings that have fallen over time) or often referred to as narrow money.

(2). Wide money supply (Y2)

The broad money supply (Y2) is commonly called broad money, the scope is wider, which is Y1 plus quasi-money (time deposits, savings, and government bonds).

(3). JISDOR Exchange Rate (X)

JISDOR (Jakarta Interbank Spot Dollar Rate) exchange rate is the USD/IDR spot price, which is prepared based on the USD/IDR transaction rate against the interbank rupiah in the Indonesian foreign exchange market which is a reference to the rupiah exchange rate against the US dollar to increase the credibility of the domestic foreign exchange market and support exchange rate stability in Indonesia.

3.4. Research Procedures

The research procedure carried out is as follows:

- a. Collect data on the Money Supply and Rupiah Exchange Rate for the period January 2017 - December 2021
- b. Test the stability of the data, if the data is not stationary, differencing or transformation is carried out.
- c. Perform an ARIMAX Model estimation and parameter significance test on the model.
- d. Diagnosis of the ARIMAX Model based on the conjecture results on the estimated model that has been obtained.
- e. Forecasting.

3.5. Data Analysis Techniques

Data analysis steps to be carried out in this study:

- a. Start analyzing data on narrow money supply and wide money supply by using Rstudio.
- b. Identifying data by creating time series plots, FAK plots and FAKP plots to see if the data is stationary. If it is not stationary in the mean, differencing is carried out and a transformation is carried out if the data is not stationary in variants.
- c. Conducting analysis with the ARIMA model by estimating the ARIMA parameters in the model so that the model coefficient is obtained if the ARIMA model obtained is significant and has met the model's goodness test, it can be added exogenous variables to the model.
- d. Analyze with the ARIMAX model (ARIMA with additional exogenous variables) by conducting a model goodness test.
- e. If all stages have been met, forecasting can be carried out.
- f. Draw conclusions..

4. Result and Discussion

4.1. Data Stationary Identification

Identification of data stationary can be done by creating time series plots, FAK plots, FAKP plots and conducting ADF tests. To see if the data has a trend and has met the stationary both in average and variance, a time series plot is made from the money supply data shown in the Figure 1.

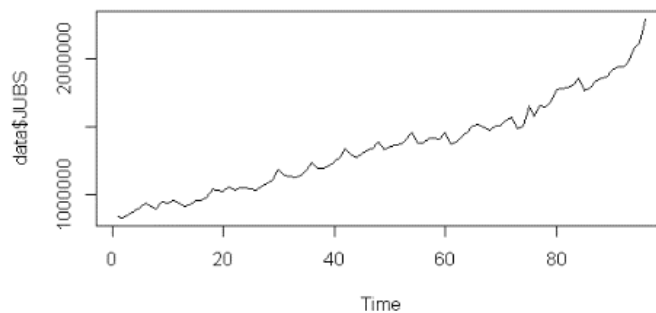


Figure 1. Time Plot Serie Data Narrow Money Supply (Y1)

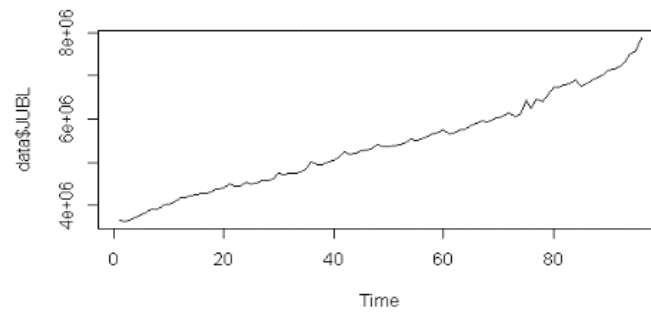


Figure 2 Time Plot Serie Data Wide Supply Money Supply (Y2)

Based on the two figures for the narrow money supply and wide money supply data above, it is known that both Y1 and Y2 data are not yet stationary in average so it needs to be differencing. At this stage, both data are differencing twice so that they produce a P-value < alpha value of 5%, which means that both data are stationary.

#### 4.2. ARIMA model identification

After the stationary conditions have been met, a temporary ARIMA model determination is carried out. At this stage, possible ARIMA models (p, d, q) will be identified against differencing result data. This identification process uses FAK and FAKP plots. The plot of FAK and FAKP the amount of money with narrow differencing results is shown in the Figure 3.

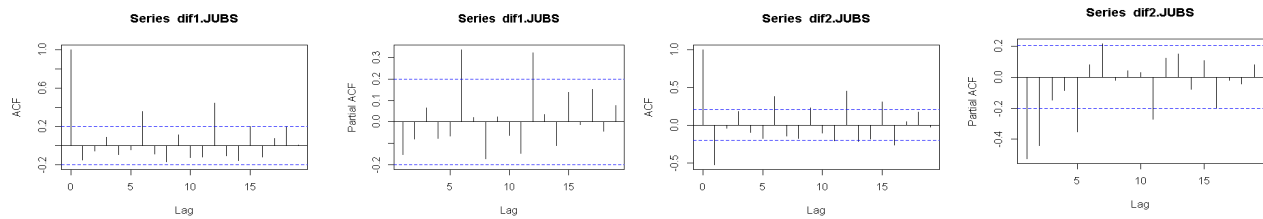


Figure 3. FAK and FAKP Plots of Differencing Narrow Money Supply

Based on Figure 3 on the narrow money supply data showing the plot of FAK and FAKP differencing first cut off at lag 6, several temporary ARIMA models were obtained, namely ARIMA(6,1,0), and ARIMA(0,1,6). Then, in differencing both FAK and FAKP plots showed temporary ARIMA models, namely ARIMA(0,2,2), ARIMA(1,2,1), ARIMA(0,2,1), ARIMA(1,2,2), and ARIMA(2,2,0). Furthermore, the FAK and FAKP plots for data on the wide money supply are attached to Figure 4.

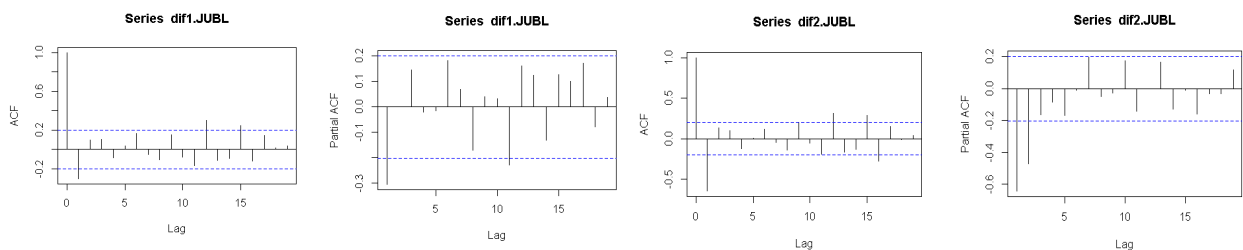


Figure 4. FAK and FAKP Plot of Differencing Wide Money Supply

Figure 4 for data on the wide money supply (Y2) shows the FAK and FAKP plots of the first and second differencing results obtained by the temporary ARIMA models, namely, ARIMA(1,1,0), ARIMA(0,1,1), ARIMA(0,2,1), ARIMA(0,2,2), ARIMA(2,2,2), ARIMA(1,2,1), and ARIMA(2,2,0).

#### 4.3. Estimation of ARIMAX Model Parameters

Parameter estimation is a ledge used to determine the model to be used. Previously, the ARIMA model was obtained while a significant test of the ARIMA model parameters was carried out for data on the money supply of Y1 and Y2 which will be used for the ARIMAX model form by adding exogenous variables, namely the exchange rate (exchange rate). The previously obtained ARIMA model will add exogenous variables in it so that the ARIMAX(0,2,2) and ARIMAX(1,2,2) models are formed for data on the narrow money supply (Y1). As for the data on the amount of money supply (Y2) formed model ARIMAX(2,2,0). Furthermore, the ARIMAX model from Y1 and Y2 data was tested for estimating ARIMAX parameters as shown on Table 1.

**Table 1.** Estimated ARIMAX Model Parameters (Y1)

Model	Parameters	Estimation	p-value	Capt.
ARIMAX (0,2,2)	$\theta_1$	-1,2166	0.0002	Significant
	$\theta_2$	0,2781	0.0332	Significant
	$e$	0,7683	0,9464	insignificant
ARIMAX (1,2,2)	$\phi_1$	0,7618	0,0008	Significant
	$\theta_1$	-1,9404	0,0002	Significant
	$\theta_2$	0,9637	0,0008	Significant
	$e$	-8.9479	0,4151	insignificant

As for the data on the amount of money supply (Y2) the ARIMA model (2,2,0) is a model that can be used to add exogenous variables so that the ARIMAX model (2,2,0) is obtained. Furthermore, the estimation of the ARIMAX model (2,2,0) is carried out as on Table 2.

**Table 2.** Estimated ARIMAX Model Parameters (Y2)

Model	Parameters	Estimation	p-value	Capt.
ARIMAX (2,2,0)	$\phi_1$	-1,0459	0.0002	Significant
	$\phi_2$	-0,5330	0,0002	Significant
	$e$	23.3308	0.1666	Insignificant

Based on Table 1 and Table 2, it can be seen that the money supply of both Y1 and Y2 has significant values of  $\phi$  and  $\theta$  parameters against the ARIMAX model. Meanwhile, exogenous data is known to have a p-value>alpha value of 5% so that the exogenous exchange rate variable is not significant in the ARIMAX model.

#### 4.4. Test Assumptions of the ARIMAX Model

After obtaining the ARIMAX model, a residual assumption examination and normal distribution test will be carried out.

##### (1). Test the Remaining White Noise

The results of the residual white noise test on Y1 data based on the output in Appendix 10 indicate that the p-value  $> \alpha = 0.05$  for the ARIMAX(1,2,2) and ARIMAX(0,2,2) models means that it accepts H0 or meets the white noise requirements. While in the Y2 data, the white noise test results for the ARIMAX model (2,2,0) in Appendix 16 show a p-value value of  $> \alpha = 0.05$  so that it accepts H0, meaning that the ARIMAX model for Y1 and Y2 data already meets the white noise requirements.

##### (2). Test the Assumption of Normal Distribution

The results of the normal distribution test with the Kolmogorov-Smirnov test for Y1 data based on the output in Appendix 11 show that the p-value of  $> \alpha = 0.05$  for the ARIMAX model(0,2,2) so that it accepts H0 and it can be concluded that the residual model meets the assumption of normality. Meanwhile, the results of the residual normality test of the ARIMAX model with the Kolmogorov-Smirnov test for Y2 data based on the output in Appendix 17 show that the p-value $< \alpha = 0.05$  for the ARIMAX model(2,2,0) so that the assumption of normality for the Y2 data with exogenous variables is met.

#### 4.5. Forecasting Accuracy

A model that can be used for forecasting narrow money supply with the addition of exogenous exchange rate variables is the ARIMAX(0,2,2) model with a MAPE value of 2.182918 resulting in the following model equation:

$$(1 - B)^2 Z_t = (1 - \theta_1 B - \theta_2 B^2) a_t + e_k X_{k,t} \tag{3}$$

$$Z_t = 2Z_{t-1} - Z_{t-2} + a_t - 1,21a_{t-1} - 0,27a_{t-2} \tag{4}$$

Meanwhile, the model that can be used to minimize the amount of money in circulation with the addition of exogenous variables is the ARIMAX model (2,2,0) with a MAPE value of 1.030971 which produces the following model equation:

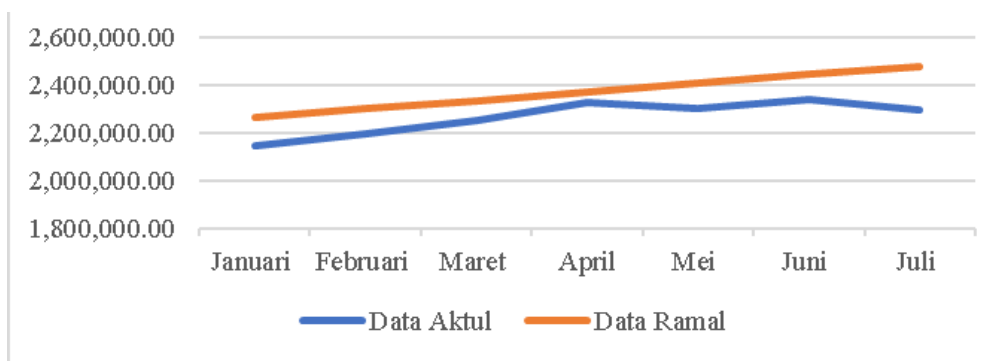
$$(1 - \phi_1 B - \phi_2 B^2)(1 - B)^2 Z_t = a_t + e_k X_{k,t} \tag{5}$$

$$Z_t = 0,96Z_{t-1} + 0,55Z_{t-2} + 0,02Z_{t-3} - 0,53Z_{t-4} + a_t \tag{6}$$

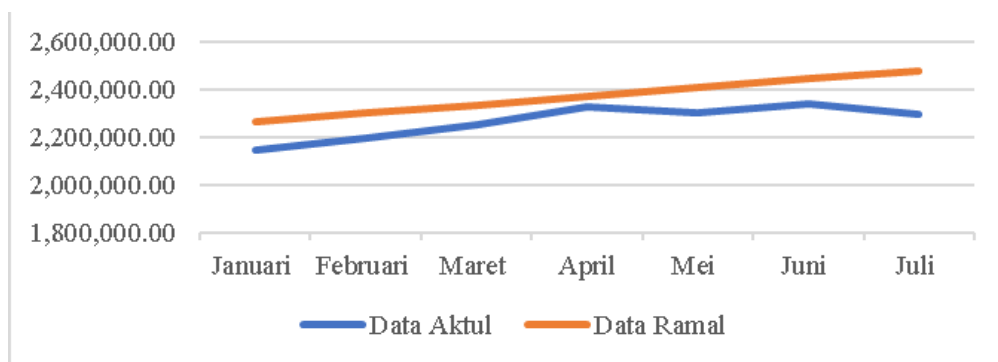
Based on the two model equations above, a significant equation was produced with the model being the ARIMA model(0,2,2) for JUBS and the ARIMA model(2,2,0) for JUBL where each money supply data had a significant effect on the model on the JUBS and JUBL data itself whereas, the exchange rate exogenous variable had no significant effect on the ARIMAX model for both JUBS and JUBL data.

#### 4.6. Forecasting

Based on the ARIMAX (0,2,2) and ARIMAX(2,2,0) models, the following are the results of forecasting the money supply data from the actual data and estimation results using the best ARIMAX model:



**Figure 5.** Comparison of Actual Data with ARIMAX Y1 Ramal Data (in Indonesia)



**Figure 6.** Comparison of Actual Data with ARIMAX Y2 Forecasting Data (in Indonesia)

Forecasting the money supply in Indonesia using the ARIMAX model results in forecasting the Y1 and Y2 money supply for the period January to December 2022 can be seen in Table 3.

Based on Table 3, it is known that the forecasting of the number of narrow money supply (Y1) and widely circulated (Y2) with exogenous variables, in 2022 both will continue to experience an increase where in January it is predicted to be 2,264,697 billion rupiah of narrow money supply in circulation and increase to 2,661,098 billion rupiah of narrow

money supply in circulation in December. Then in January 2022 the amount of widely circulated money is predicted to circulate of 7,666,219 billion rupiah and continues to increase until December of 9,737,874 billion rupiah.

**Table 3.** Forecasting the Money Supply in Indonesia (Y1 and Y2) in Billion Rupiah

Period	Forecasting Y1	Forecasting Y2
Januari 2022	2.264.697	7.666.219
Februari 2022	2.300.733	7.855.708
Maret 2022	2.336.770	8.070.903
April 2022	2.372.806	8.227.827
Mei 2022	2.408.843	8.431.996
Juni 2022	2.444.879	8.617.810
Juli 2022	2.480.916	8.797.640
Agustus 2022	2.516.952	8.993.512
September 2022	2.552.989	9.175.795
Oktober 2022	2.589.025	9.363.741
November2022	2.625.062	9.553.007
Desember 2022	2.661.098	9.737.874

## 5. Conclusion

The forecasting model of the money supply in Indonesia using the ARIMAX model produces the best model, namely ARIMAX (0,2,2) for a narrow money supply with forecasting accuracy can be seen in the MAPE value of 2.18. While the best model for forecasting the amount of money in Indonesia is ARIMAX(2,2,0) with forecasting accuracy seen at the MAPE value of 1.03.

The results of forecasting the money supply in Indonesia for the period January 2014 to December 2021 using the ARIMAX model (0,2,2) for narrow money supply and the ARIMAX model (2,2,0) for the wide money supply, it is known that the variable that has a significant effect on the money supply in Indonesia, both Y1 and Y2, is the money supply itself. Meanwhile, the exchange rate exogenous variables are not significant for the ARIMAX model(0,2,2) for the Y1 data and the ARIMAX model(2,2,0) for the Y2 data. So that the significant models in this study are the ARIMA (0,2,2) and ARIMA(2,2,0) models.

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