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Forecasting Inflation in Indonesia Using ARIMAX : The Role of Money Supply and Exchange Rate

Besti Novianda*

Department of Economics, Faculty of Economics and Business, Universitas Andalas, Indonesia
* Correspondence: bestinovianda@feb.unand.ac.id

Abstract: *Inflation is an essential economic indicator since it signals rising prices for goods and services. Economic factors influence Indonesia's inflation rate, including the money supply and exchange rate. These factors can have an impact not only on inflation at a single point in time but also throughout time. The money supply and exchange rate are two economic factors that substantially influence inflation. As a result, it is critical to forecast Indonesia's inflation rate using the money supply and exchange rate as input variables. This study examines the effect of the money supply and exchange rate on the inflation rate. The data used is monthly from 2021 to 2023, sourced from Bank Indonesia (SEKI BI). This study used the Autoregressive Integrated Moving Average with Exogenous Factor (ARIMAX) technique. The results reveal that the ARIMAX (0,2,1) accurately predicts inflation, as seen by MAPE values of 9.48%. The results also show that the money supply and exchange rate significantly affect the inflation rate in Indonesia. This is due to the impact of the COVID-19 pandemic on Indonesia, which has caused the inverse effect of the exogenous variables. The ARIMAX model can be a valuable and efficient tool for improving forecasting.*

Keywords: Inflation Rate, Money Supply, Exchange Rate, Forecasting, ARIMAX

JEL: E51, E4

1. INTRODUCTION

Inflation is one of the most pressing economic issues for governments worldwide (Adão & Silva, 2021; Akinsola & Odhiambo, 2017; Oktavia & Wahyudi, 2022). Inflation is one of the macroeconomic indicators used to assess a country's financial stability (Shafira, 2023; Yilmazkuday, 2022). Inflation rates should be kept low and stable so that macroeconomic problems do not arise and cause economic instability. As the world's fastest-growing economy, Indonesia is constantly experiencing changes and challenges in maintaining macroeconomic stability (Markus & Muchtar, 2023; Siregar et al., 2023). Some significant factors influencing Indonesian economic growth are the domestic interest rate, the amount of money available, and the currency's value. The second factor significantly impacts Indonesia's financial situation and development.

The amount of money in circulation significantly affects the Indonesian economy, influencing the overall inflation rate, investment, and economic growth (Cili & Alkhaliq, 2022; Kurniasih, 2019). The amount of money in circulation is a demand-side factor contributing to inflation. The funds provided to the public should be appropriate to their needs or desires (Jumlah et al., 2020). Therefore, a thorough analysis of macroeconomic factors is essential to understand the dynamics of the Indonesian economy (Bina et al., 2023; Sumiyati, 2022).

On the other hand, a currency's value reflects a country's economic strength in the international market (Jamil et al., 2023; Jin et al., 2021; Stavrakeva & Tang, 2023). Fluctuations in the exchange rate of the rupiah against foreign currencies not only affect the public's purchasing power but also the export and import sectors (Junia, 2023; Pangestuti et al., 2022; Pratiwik & Prajanti, 2023). Changes in exchange rates can be an indicator of economic instability. Therefore, maintaining the amount of money in circulation, the value of the currency, and controlling inflation are some of the government's and central bank's goals in ensuring economic stability (Samargandi et al., 2020; Bina et al., 2023). The influence of the amount of money in circulation and exchange rates in Indonesia must be distinct from the dynamics of the global economy (Amhimmid et al., 2021; Bank Indonesia, 2022; Sugandi, 2022). As economic interconnections between countries become increasingly close, changes in the international financial market can quickly impact the Indonesian economy (McKinsey Global, 2014).

Based on data from the Indonesian Economic and Financial Statistics (2023), Indonesia's macroeconomic data from 2013 to 2023, including the money supply (in billions of rupiah), inflation rate, rupiah exchange rate against the US dollar, and Bank Indonesia's benchmark interest rate (BI Rate). During this period, the money supply showed a consistent upward trend, rising from Rp3.730 trillion in 2013 to Rp8.824 trillion in 2023. The inflation rate generally declined, reaching a low of 1.68% in 2020, before sharply increasing to 5.51% in 2022 and then declining again in 2023. The rupiah exchange rate also experienced fluctuations, with significant depreciation until 2022 and slight appreciation in 2023. Meanwhile, the BI Rate showed a downward trend from 2013, reaching a low of 3.5% in 2021 in response to the pandemic, before rising again to 6% in 2023 as monetary policy normalized. This data reflects the dynamics of Indonesia's monetary policy in responding to domestic and global economic conditions over the past decade.

Inflation is an economic phenomenon that directly affects price stability and purchasing power. Factors such as money supply and currency exchange rates have long influenced inflation. Money supply, which reflects economic liquidity, can trigger inflation if its growth is not balanced with economic output. On the other hand, the exchange rate is vital in influencing the price of imported goods, affecting the overall domestic price level. As Indonesia is one of the developing countries, an increase in the money supply is often associated with loose monetary policy to boost economic growth. However, this can also lead to uncontrolled inflation if not matched by increased productivity. Volatile exchange rates, especially Indonesia's currency, which is susceptible to external shocks, are also a significant factor in influencing the prices of imported goods, directly impacting Indonesia's inflation.

Although the relationship between money supply, exchange rate, and inflation has been widely discussed in economic literature, research gaps still exist in some aspects. This study integrates two key variables, namely money supply and exchange rate, which are theoretically and empirically known to influence inflation. As such, it offers a more comprehensive analysis than previous studies examining only one variable separately. Based on the above thoughts, researchers try to forecast the inflation rate data in Indonesia by entering the money supply and exchange rate as exogenous variables. The data used is time series data. Time series data can change over time and sometimes suddenly, such as due to external shocks or unexpected economic policies. Therefore, forecasting is needed to see these changes and determine the impact of the money supply and exchange rate on forecasting the inflation rate in Indonesia. Using a time series forecasting approach, this research can help anticipate possible inflation volatility caused by exchange rate fluctuations or changes in monetary policy related to money supply.

This study uses data from the COVID-19 pandemic era in the ARIMAX model to predict inflation in Indonesia, which is expected to provide significant benefits, especially in capturing unusual economic dynamics and extreme policy responses. The COVID-19 pandemic created a major shock to inflation, both on the demand and supply sides. By incorporating data from this period, the ARIMAX model is expected to more accurately measure how inflation responds to changes in the money supply and the rupiah exchange rate amid crisis conditions. The pandemic period also reflects loose monetary policies (such as interest rate cuts and increased liquidity) as well as exchange rate volatility, which strengthens the role of exogenous variables in influencing inflation.

In addition, data from the COVID-19 pandemic era allows the model to capture changes in the short-term structural relationship between inflation and other macroeconomic variables. The use of the ARIMAX model is expected to enhance the model's resilience and flexibility in predicting future inflation, particularly in the face of similar shocks. Thus, researchers aim to conduct inflation forecasts and demonstrate whether the use of COVID-19 pandemic data can strengthen model predictions while also providing strategic value in determining appropriate macroeconomic policies for Indonesia.

Through an in-depth analysis of this phenomenon, it is hoped that appropriate policy solutions can be found to maintain Indonesia's macroeconomic stability, enhance economic growth, and reduce the risks of fluctuations in money supply and exchange rates. This research is expected to contribute to global understanding of the financial dynamics of developing countries, particularly Indonesia, which faces increasingly complex global challenges.

2. LITERATURE REVIEW

Theoretical Framework

The link between money supply and exchange rate to inflation rate has been widely studied. Two theories predict how the money supply and exchange rate will increase the inflation rate in Indonesia. They are the Irving Fisher Theory and the Cambridge Theory (Marshall- Pigou).
Irving Fisher was formulated as follows:

$$M.V = P.T \qquad (1)$$

With M as the money supply, V as the velocity or speed of money movement, P as the price, and T as the number of transactions that occur in the economy. This theory explains that the change in the money supply would be proportional to the change in price if V and T were assumed to be constant.

Fisher explains that the product of the amount of money and the velocity of money circulation must be equal to nominal income (P x T). The acceleration of the amount of money in circulation is determined by the economic institutions implementing policies that can influence people's transactions. However, the condition of an economy's institutions and technology will affect the speed of money circulation. If institutions and technology are efficient, money circulation will continue, resulting in long-term changes. In the short term, the demand for money tends to remain constant.

Mankiw (2022) defines inflation as a sustained rise in the general prices for goods and services throughout the economy, which results in a continuous decline in the national currency's purchasing power. However, it is difficult to explain and regulate because inflation is a potentially very effective tool that can affect economic conditions, such as a short-term trade-off between unemployment and inflation. Monetarists advocate that the rate of inflation ($increment$) should equal the growth rate of the nominal money supply (Δm_t^s) minus the growth rate of actual demand ($\Delta \frac{m^d}{p_t}$) (Chang & Velasco, 2001).

$$\Delta p_t = (\Delta m_t^s) - (\Delta \frac{m^d}{p_t}) \qquad (2)$$

Equation 2 illustrates the relationship between money supply and money demand in determining changes in the price level or inflation from one period to the next. All variables are in logarithmic form. Δ denotes the first difference operation, and t captures time.

The primary actual money demand function can be expressed as the following:

$$\frac{m^d}{p_t} = f(y_t, r_t) \qquad (3)$$

Actual money demand is a function of income (y_t) and prevailing domestic interest rate (r_t). Equation 3 illustrates that actual money demand is influenced by real income and actual interest rates in an economy. The higher the actual income and the lower the real interest rate, the more likely the actual money demand will increase, and vice versa. Through previous research, we define the following essential actual money demand function to account for the external factors.

$$\frac{m^d}{p_t} = f(y_t, r_t, \varepsilon_t) \qquad (4)$$

Based on equation 4, where (ε_t) is the expected depreciation of local currency (exchange rate) during this period. The effect of the exchange rate on the economy can be through several channels: 1. Effects on foreign purchasing power: If the exchange rate of a currency weakens (declines), then foreign purchasing power can also decline. The value of exports will fall because domestic product prices become expensive and vice versa. They ultimately affect real income in the country. 2. Effect on inflation rate: Domestic currency depreciation may increase import prices, leading to inflationary pressures and vice versa.

Next, substituting equation 4 into equation 2 will yield the following general expression for domestic inflation:

$$\Delta p_t = (\Delta m_t^s) - f\ (\Delta y_t, \Delta r_t, \Delta \varepsilon_t) \quad (5)$$

$$\Delta p_t = f(\Delta m_t^s) - f\ (\Delta y_t, \Delta r_t, \Delta \varepsilon_t) \quad (6)$$

$$\Delta p_t = f\ (\Delta y_t, \Delta r_t, \Delta \varepsilon_t, \Delta m_t^s) \quad (7)$$

Equation 7 suggests that the level of domestic inflation will be influenced by the changes in the level of domestic income, domestic and foreign interest rates, expected depreciation of the local currency (the exchange rate factor), and domestic money supply. In this study, the variables used are economic growth, interest rate, money supply, and exchange rate, so the derivative is only in these four variables. The following first-order conditions should hold.

$$\frac{\partial \Delta p_t}{\partial \Delta y_t} < 0 \quad (8)$$

Based on equation 8, as output and income increase, the demand for money will also rise. If the money supply remains constant, the inflation rate will decrease as the demand for money increases compared to the money supply. Therefore, the increase in output will eventually result in a decrease in the inflation rate.

$$\frac{\partial \Delta p_t}{\partial \Delta r_t} > 0 \quad (9)$$

Equation 9 suggests that if domestic interest rates increase, the opportunity cost of holding money will increase, and the demand for money should decrease. Domestic inflation should rise because there is a decrease in money demand, even though the money supply remains unchanged.

$$\frac{\partial \Delta p_t}{\partial \Delta \varepsilon_t} > 0 \quad (10)$$

Equation 10 states that if there is an increase (or smaller decrease) in the exchange rate, then the change in the inflation rate will tend to increase as well. This indicates a positive relationship between these external variables and the inflation rate.

A rise in (ε_t) Reduces money demand in the absence of any other changes. As a result, the domestic economy will have a comparatively larger money supply than demand. Thus, a rise in inflation is anticipated.

$$\frac{\partial \Delta p_t}{\partial \Delta m_t^s} > 0 \quad (11)$$

Equation 11 states that an increase in the money supply should boost domestic inflation if all other factors remain constant.

Previous Research

Research by Oktavia & Wahyudi (2022) discusses the application of the ARIMAX model in forecasting inflation in Indonesia, taking into account the role of money supply and exchange rates as external variables. The results of the study show that both money supply and exchange rates have a significant effect on inflation, with increases in money supply and depreciation of exchange rates driving inflation. The ARIMAX model also demonstrates better predictive capabilities compared to the standard ARIMA model, as it incorporates relevant external factors. Overall, the results of this study indicate that the ARIMAX model is an effective tool for forecasting inflation in Indonesia, and the use of exogenous variables such as money supply and exchange rate can improve prediction accuracy. These findings provide important contributions to the formulation of monetary policy, particularly in maintaining price stability through the control of factors that directly influence inflation.

The study by Eksiandayani et al (2015) discusses the application of ARIMAX and NN models to forecast inflation in Indonesia, taking into account the money supply as an external factor. In this study, the data used consists of monthly inflation data and money supply (M2) data from January 2000 to June 2015. The results of the study indicate that the ARIMAX model shows that an increase in the money supply of 0.22% can lead to an increase in inflation of 1%.

Research conducted by Coker (2025) developed and compared three time series models, ARIMA, ARIMAX, and VAR(p), for short-term inflation forecasting in Sierra Leone to support evidence-based monetary policy making. The results show that the ARIMAX model is significantly better than the ARIMA and VAR(p) models. These findings confirm that the exchange rate is a key factor in short-term inflation dynamics in Sierra Leone. The superiority of the ARIMAX model emphasizes the importance of incorporating exogenous information (exchange rate) into the inflation forecasting framework. Policymakers should closely monitor exchange rate movements as a leading indicator of inflation.

3. METHOD

To achieve the effect of money supply and exchange rate on the inflation rate, the analysis technique in this study uses a quantitative approach using the Autoregressive Integrated Moving Average Exogenous (ARIMAX), which is a modification of the ARIMA model by adding exogenous variables (Kongcharoen & Kruangpradit, 2013; Osagie Adenomon & Oshuwalle Madu, 2023). Exogenous variables or independent variables are factors that have the potential to influence other variables in the model but are not influenced by other variables in the model. In this study, the exogenous variables used are money supply and exchange rate, while the inflation rate variable is used as a time series variable in the analysis.

The formation of the ARIMAX model begins with time series regression modeling. In time-series data $(Z_t, t \in \mathbb{Z}$ The first test performed was that the data must be stationary. If the error of the time is a regression model (ε_t) s Met the white noise assumption, the residuals of the time series regression model are modeled using the ARIMA model. According to Rzepczynski (2006), in the white noise process, there are two data stationarity behaviors : (1) Mean stationarity means that the expected value of the time series does not depend on time, $\in (Z_t)$ does not depend on t, where t = time. Data is stationary at (zero) or at the "level." If it is not stationary at the level, first differencing and second differencing will be done to see to what extent the data is stationary. (2) The autocovariance functions defined $Cov\ (Y_t, Y_t + k)$ for each lag k is only $k$and not time; that is, γ $(Y_t, Y_t + k)$, or γ $(Y_t, Y_t + k)$ independent of t for every k or is called variance stationarity σ2. If the variant is not stationary, the data will be transformed.

In this study, the form of ARIMA (p, d, q) model for time series x_t Ch is inflation rate data or variables is as follows:

$$\phi_P(B)(1-B)^d x_t = \mu + \theta_q(B)\varepsilon_t \quad (1)$$

Description :

μ	= intercept
B	= lag operator
p dan q	= non-seasonal order autoregressive and non-seasonal order moving average
d	= order differencing non-season
$\phi_P(B)$	= non-seasonal autoregressive component
$\theta_q(B)$	= non-seasonal moving average component
$(1-B)^d$	= non-seasonal differencing

The steps taken to obtain the ARIMAX model include: (1) Pass the data stationarity test using the Augmented Dickey-Fuller Test (ADF) and model identification by determining orders based on lag correlation analysis using Correlogram ACF and PACF. (2) Selection of the best candidate model, which is carried out based on parameter significance and the smallest AIC (Akaike info criterion) and Bayesian Information Criterion (BIC) values. Parameter significance test at the level α = 5% is conducted to select the best candidate model. (3) Thirdly, diagnostic checking is carried out by testing the assumptions of the white noise of the model, namely the autocorrelation test of the residuals and the heteroscedasticity test of the residuals. If the Correlogram - Q - statistics shows a probability value at each lag that is greater than α = 5%, then the sisaan does not have a sisaan autocorrelation. Meanwhile, if the Prob value on the Correlogram Squared Residuals is more significant than alpha = 5% at each lag, it means that the variance of the residuals is not heteroscedasticity.

Money supply and exchange rate variables are used as exogenous variables. The consideration is based on the theory that the relationship between money supply and the exchange rate is closely related to the inflation rate. Furthermore, after passing the diagnostic check, the exogenous variable z_t (money supply and exchange rate) is entered into equation (1) so that the following ARIMAX equation is obtained:

$$\phi_P(B)(1-B)^d x_t = \mu + \sum_{i=1}^{k} \alpha_i Z_{ti} + \theta_q(B)\varepsilon_t \qquad (2)$$

ARIMAX modeling is performed using the best ARIMA model. After that, the activities of the second and third stages above were applied to the resulting ARIMAX model to obtain a model ready for forecasting. Meanwhile, data processing uses R software. Thus, the ARIMAX models are estimated using the Ordinary Least Squares (OLS-ARMA) method.

The measurement of the forecasting accuracy of the testing data is carried out using MAPE (Mean et al.), which is formulated as follows :

$$MAPE = \frac{1}{V-T}\sum_{t=T+1}^{V}\left|\frac{F_t - A_t}{A_t} x\ 100\%\right| \qquad (3)$$

With F_t is the result of forecasting period *t* and A_tIs the actual value of the period *t*. A model's forecasting accuracy level is divided into four groups based on MAPE. First, perfect (MAPE ≤ 10%). Second, good (10% < MAPE ≤ 20%). Third, quite good (20% < MAPE ≤ 50%). Fourth, bad (MAPE > 50%).

The data used in this study are monthly money supply and exchange rate data of Indonesia from July 2018 - Dec 2023 obtained from bi.go.id. The period data is used as training data to form forecasting models. While the data for the period January 2023 - December 2024 is used for testing forecasting.

4. RESULTS AND DISCUSSION

In building the ARIMAX model of the inflation rate, the data is checked to determine whether the data has been stationary in variance and mean. Graphically, Figure 1 presents the pattern data of inflation rate, money supply, and exchange rate.

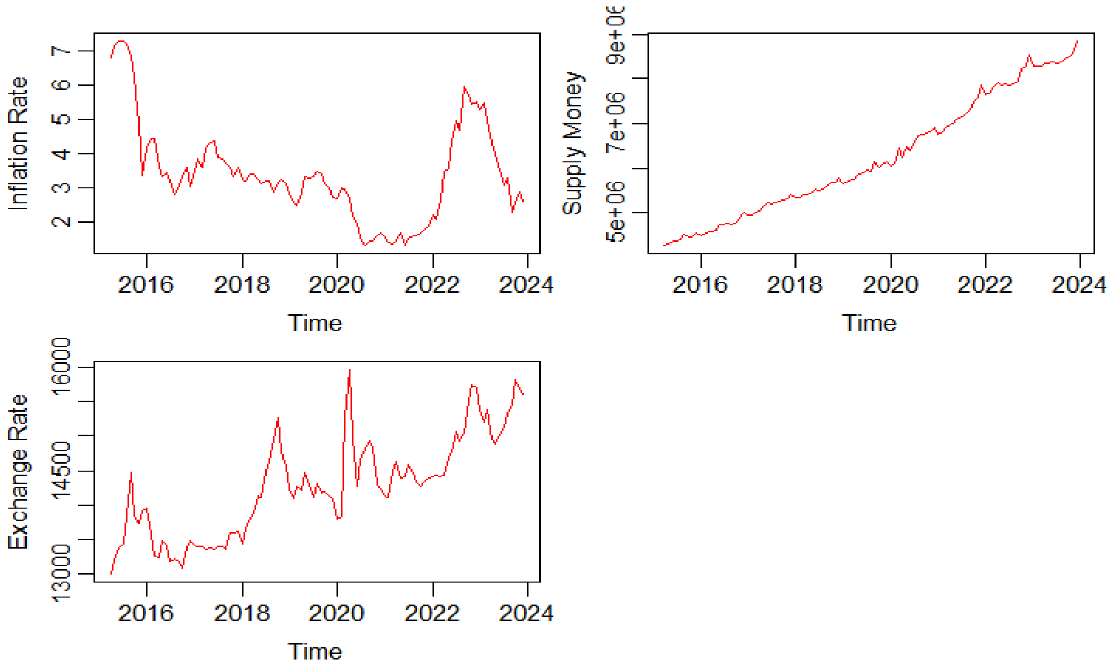

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Figure 1. Graph of inflation rate (percentage), money supply (billion IDR), exchange rate (IDR), and BI rate (percentage) in Indonesia during 2013-2023.

Based on Figure 1, the pattern data of the inflation rate does not fluctuate around the mean value, so it can be assumed that the data has not been stationary. Consequently, the data must be checked using Box-Cox and Augmented Dickey-Fuller to determine whether the data has to be transformed and whether there is a unit root in the time series data.

Table 2. Transformation parameter of inflation rate using the Box-Cox method

	1st Transformation	2nd Transformation
Parameter (λ)	**0.1891**	1

Source: data processed, 2024

Table 2 presents the transformation parameter of the inflation rate, denoted as λ. Based on Table 2, the inflation rate has to be transformed by performing the power calculation of the inflation rate with an exponent of 0.1891 in the first transformation. After the data is transformed, the parameter in the second transformation is 1. This means the data has been stationary in variance because it will be itself when the exponent of 1 is used. Therefore, the transformed data must be checked using the Augmented Dickey-Fuller (ADF) to determine whether the transformed data has been stationary in the mean. The ADF test examines time series to determine whether the transformed inflation rate data are stationary in mean or contain a unit root. (Dickey & Fuller, 1981). In the ADF test, the stationary data will be fulfilled if the probability value is smaller than the significance level. Table 3 presents the unit root test result using the ADF test.

Table 3. Unit root test using the augmented Dickey-Fuller test for the transformed inflation rate

	Statistic Value	Probability Value
Transformed data	**-2.6961**	0.2880
1st Differencing	-3.4115	0.0564*
2nd Differencing	-6.7812	0.0100***

Note: level of significance ($\boldsymbol{\alpha}$): 1%***, 5%**, 10%*
Source: data processed, 2024

Based on the results in Table 3, the inflation rate's probability value is smaller than that. A$\alpha = 0.05$ $after$ a second-order differencing. This means the data has to be differenced twice to be stationary in the mean because there are unit root problems with transformed data (without differencing) and after first-order differencing.

The next step is determining the order of ARIMAX (p,d,q), where 'p' represents the autoregressive order, 'd' is the differencing order, and 'q' represents the moving average order. This is accomplished by analyzing Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots. Generally, the ARIMA model requires data that has been stationary in constructing ACF and PACF plots, which indicates that the residual data will be distributed as white noise. Based on the result of the ADF test, the different order $d = 2$. This means that stationarity is achieved through second-order differencing. In building the ARIMAX model, the exogenous variables must also be considered to determine the maximum significance lags in ACF and PACF. Consequently, the parameters of exogenous variables (supply money and exchange rate) have to be checked to determine whether the parameters of supply money and exchange rate are already significant toward the inflation rate. In other words, the significance parameters of supply money (Z_{t1}) and natural logarithm of the exchanger (Z_{t2})) Ll determined whether they significantly impact the inflation rate. Table 4 presents the linear regression results of the inflation rate as the dependent variable and supply money and exchange rate as independent variables using the ordinary least squares method.

Table 4. Linear regression of exogenous variables.

Parameter	Estimate	Standard Error	t-value	p-value
Z_{t1}	**-3.092e-07**	1.028e-07	-3.008	0.0033 ***
Z_{t2}	5.581e-01	6.867e-02	8.128	1.02e-12 ***

Note: level of significance ($\boldsymbol{\alpha}$): 1%***, 5%**, 10%*
Source: data processed, 2024

Table 4 shows that the exogenous variables significantly impact the inflation rate based on the probability values of supply money and log(exchange rate) less than the significance level of 5%. The following figures show the significant lags contained in ACF and PACF in determining the moving average and autoregressive orders, respectively.

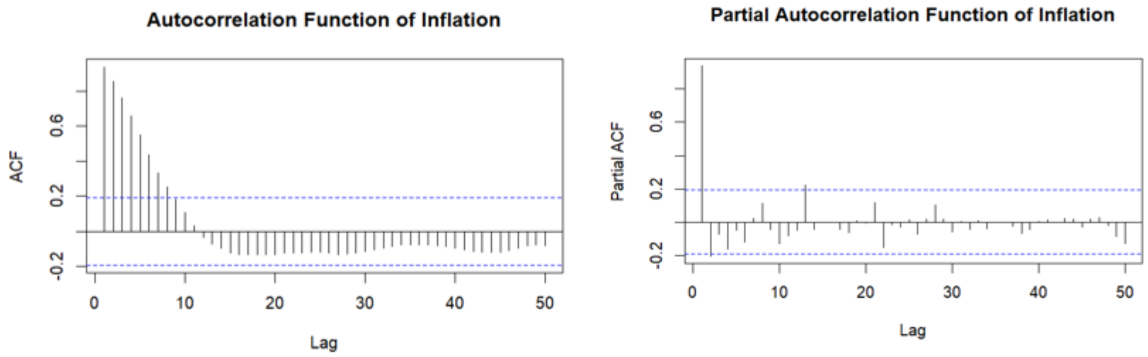

Figure 2. Autocorrelation Function and Partial Autocorrelation Function of Inflation Rate.

Based on Figure 2, the maximum significance lags of ACF and PACF, respectively, are 8 and 2, so the maximum significance of the ARIMAX model formed is ARIMAX(2,2,8). However, ARIMAX(2,2,8) is not the optimal ARIMAX model because the best model has to be selected using the Akaike Information Criterion (AIC) and the significance parameters for each model. The combination that can be built by using order of AR (p=2) and order of MA (q=8) with second-order differencing is 26 models, the possible ARIMAX model are ARIMAX(0,2,1), ARIMAX(0,2,2), ARIMAX(0,2,3), ARIMAX(0,2,4), ARIMAX(0,2,5), ARIMAX(0,2,6), ARIMAX(0,2,7), ARIMAX(0,2,8), ARIMAX(1,2,1), ARIMAX(1,2,2), ARIMAX(1,2,3), ARIMAX(1,2,4), ARIMAX(1,2,5), ARIMAX(1,2,6), ARIMAX(1,2,7), ARIMAX(1,2,8), ARIMAX(2,2,1), ARIMAX(2,2,2), ARIMAX(2,2,3), ARIMAX(2,2,4), ARIMAX(2,2,5), ARIMAX(2,2,6), ARIMAX(2,2,7), ARIMAX(2,2,8), ARIMAX(1,2,0), and ARIMAX(2,2,0).

Among 26 possible ARIMAX models, three possible ARIMAX models have significant parameters. Three possible ARIMAX model are ARIMAX(0,2,1), ARIMAX(1,2,0), and ARIMAX(2,2,0). Table 5 shows the estimated parameters of three possible ARIMAX models with exogenous variables of supply money (Z_{t1}) and natural logarithm of the exchange rate (Z_{t2}).

Table 5. Estimated parameters of ARIMAX(p,2,q)

Model	Parameter	Estimate	z-value	p-value	AIC
ARIMAX(0,2,1)	**: MA(1)**	**-8.7992e-01**	-8.7964	< 2e-16 ***	-834.1047
	$\boldsymbol{Z_{t1}}$	**-1.9538e-09**	-2.0505	0.0403 **	
	$\boldsymbol{Z_{t2}}$	**1.5863e-02**	60.4173	< 2e-16 ***	
ARIMAX(1,2,0)	θ_1 : AR(1)	-4.1908e-01	-4.6769	2.912e-06 ***	-806.9664
	Z_{t1}	-2.5264e-09	-2.5860	0.0098 ***	
	Z_{t2}	6.8938e-04	3.3714	0.0008 ***	

ARIMAX(2,2,0)	θ_1 : AR(1)	-5.8406e-01	-6.4471	1.140e-10 ***	-822.409
	θ_2 : AR(2)	-4.0291e-01	-4.5078	6.551e-06 ***	
	Z_{t1}	-2.8759e-09	-3.0548	0.002252 ***	
	Z_{t2}	1.8424e-02	83.3353	< 2.2e-16 ***	

Note: level of significance ($\boldsymbol{\alpha}$): 1%***, 5%**, 10%*
Source: data processed, 2024

Table 5 shows the estimated parameters of three possible best ARIMAX model(p,2,q) with their AIC values. Based on the AIC values in Table 4, the ARIMAX(0,2,1) model has the smallest value compared to other models. The ARIMAX(0,2,1) model is the best for inflation rate data. Therefore, ARIMAX(0,2,1) model of inflation rate (X_t) This can be expressed as follows:

$$(1-B)^2 X_t = -0.8799\,\varepsilon_{t-1} + \varepsilon_t - 1.9538 \times 10^{-9} Z_{t1} + 1.5863 \times 10^{-2} Z_{t2} \quad \text{.....................(4)}$$

In equation 8, in theory, money supply has a positive effect on inflation in that an increase in money supply will increase transactions of goods and services, which, in turn, will affect the inflation rate. However, in this study, the money supply has the opposite effect. One situation where the money supply negatively affects inflation is when the economy is experiencing a recession or economic stagnation. This is also because this study uses Indonesian data from the start of the COVID-19 pandemic. Under these conditions, even though the central bank increases the money supply, the demand for goods and services remains low. As a result, the increase in money supply will not trigger a significant price increase, as there is not enough intense demand pressure. In addition, tight and efficient monetary policy, such as aggressive interest rate hikes by the central bank, can also reduce the impact of an increase in the money supply on inflation.

The negative impact of money supply on inflation in Indonesia post-COVID-19 occurred due to a combination of weak aggregate demand, monetary transmission failure, and structural economic factors. In a recession, even though Bank Indonesia increases liquidity through quantitative easing and interest rate cuts, households and businesses tend to hoard funds or repay debts rather than increase consumption and investment, so money does not flow into the real sector, and the multiplier effect weakens. Deflationary expectations also emerge, encouraging delayed spending that further depresses inflation. On the other hand, monetary policy transmission is hindered by banking risks, which prefer safe instruments such as government bonds over extending credit to SMEs, while the dominance of the informal sector and reliance on stable global commodity prices keep domestic inflationary pressures low. The BI's strict macroprudential policies and the growth of digital transactions (e-money) have also reduced the velocity of money, so that the increase in money supply has not been accompanied by a significant increase in money circulation, resulting in a negative relationship between money supply and inflation during this period.

From equation 8, it is known that the exchange rate positively affects inflation. This happens because of the depreciation of the domestic currency. Domestic currency depreciation makes the price of imported goods higher in domestic currency. This happens because it takes more units of the domestic currency to buy the foreign currency needed to import the goods. As a result, the price of imported goods rises, which can drive inflation. Currency depreciation can also increase production costs for firms that rely on imported raw materials or equipment. When production costs increase, firms tend to pass the costs on to consumers by raising the prices of their goods and services, which can lead to inflation. In addition, domestic currency depreciation can also affect people's consumption patterns. When the prices of imported goods rise, consumers tend to switch to cheaper domestic goods. However, if domestic goods increase in price due to higher production costs, this may lead to inflationary pressures.

In determining the accuracy of the ARIMAX(0,2,1) model, the mean absolute percentage error (MAPE) is required. The MAPE value of the ARIMAX(0,2,1) model is

$$MAPE = \frac{1}{105}\sum_{t=1}^{105}\left|\frac{X_t - A_t}{A_t}\right| \times 100\% = 0.094844 = 9.4844\%$$

The MAPE value of 9.4844%, less than 10%, indicates that the ARIMAX(0,2,1) model has excellent accuracy. Therefore, the ARIMAX model can be used to forecast the future values. Table 6 presents the predicted value for three months ahead, associated with the actual value for three months ahead in 2024.

Table 6. Forecasted value for three months ahead in 2024.

Month	Value		Standard Error	Confidence Interval		Decision
	Actual	Forecasting		Lower	Upper	
January 2024	0.0257	0.0253	0.0041	0.0213	0.0294	in interval
February 2024	0.0275	0.0243	0.0061	0.0182	0.0304	in interval
March 2024	0.0305	0.0233	0.0079	0.0154	0.0312	in interval

Source: data processed, 2024

Table 6 shows the actual and forecasted values of the inflation rate in January 2024, February 2024, and March 2024. The results in Table 6 also show that all actual values of inflation rates on January 2024, February 2024, and March 2024 are interval. For instance, the exact value of the inflation rate in January 2024, which is 0.0257, is between a lower limit of 0.0213 and an upper limit of 0.0294. It also shows the forecasted value of January 2024, which is 0.0253, with a slight error of about 0.0004. It means that the ARIMAX(0,2,1) model can precisely predict the future values of the inflation rate.

The ARIMAX(0,2,1) model is capable of predicting Indonesia's inflation rate for January–March 2024 with high accuracy, as evidenced by the minimal difference between actual and predicted values (e.g., January 2024, error 0.0004). The actual values are always within the prediction interval (e.g., January 2024 inflation of 0.0257 is within the range of 0.0213–0.0294), indicating that this model is not only precise but also reliable in capturing inflation volatility. These results are consistent with the relatively stable post-COVID-19 inflation characteristics due to BI's tight monetary policy and aggregate demand that has not yet fully recovered. The success of this model is supported by the integration of exogenous variables (such as money supply or interest rates) in ARIMAX, which improves the weakness of the conventional ARIMA model in capturing the influence of external factors.

These findings are in line Newton et al (2020) showed that the best model was ARIMAX(2,0,3) with all independent variables, which produced forecast results that were quite close to the actual data, although not statistically significant. Overall, this study demonstrates that the ARIMAX approach with big data, such as Google Trends, can enrich regional inflation predictive models. Next, the research results conducted by Rukini (2015) show that the ARIMAX(1,1,1) model, with the selected exogenous variables, provides a reliable inflation forecast, outperforming simpler ARIMA models in terms of prediction accuracy. This study concludes that incorporating relevant macroeconomic indicators into time series models like ARIMAX enhances their predictive performance and supports more informed economic decision-making.

5. CONCLUSION AND SUGGESTION

CONCLUSION

The data analysis revealed that the inflation rate follows a long-memory data pattern. It can be observed that inflation data follows a long-memory pattern. This value is indicated by the ACF plot, which has decreased. Past data significantly influences current data, which will decrease over time. Time series data for the inflation rate can be formed into the model, producing appropriate parameter estimates and high accuracy, indicating a close relationship to the actual data. The computed accuracy number is close to the original data, with a MAPE value of 9.48%. The ARIMAX model provides accurate forecasting results.

The ARIMAX model has critical implications for policy authorities. First, Bank Indonesia can utilize this model for forward-looking monetary policy, such as adjusting interest rates or the money supply earlier, given that current inflation is influenced by persistent historical trends. Second, the government can design more responsive fiscal policies (such as subsidies or tax incentives), especially in the face of external shocks, as this model is capable of predicting the long-term impact of policy interventions. Third, the inflation stability predicted by this model underscores the need for coordination between BI and the Ministry of Finance to avoid contradictory policies, while strengthening policy synergy in maintaining inflation within the target band. Thus, these results not only strengthen macroeconomic planning but also reduce uncertainty in decision-making.

SUGGESTION

This study has several limitations that need to be considered. First, the ARIMAX model assumes a linear relationship in inflation time series data, so it may not be able to capture complex nonlinear patterns, especially during periods of economic instability or external shocks such as pandemics or global commodity price fluctuations. Second, the accuracy of this model is highly dependent on the selection of appropriate exogenous variables, and the unavailability of real-time data or incomplete data may affect predictive performance. Third, although the MAPE of 9.48% indicates good results, this value may still be suboptimal for policy planning that requires high precision in highly dynamic economic situations.

To overcome these limitations, further studies could compare the performance of ARIMAX with machine learning methods such as Long Short-Term Memory (LSTM), which is capable of capturing nonlinear relationships and long-term dependencies in inflation data. In addition, hybrid models combining ARIMAX with neural networks (e.g., ARIMAX-NN) could be developed and tested to leverage the advantages of both approaches. Further research should also expand the scope of exogenous variables by incorporating factors such as market sentiment, fiscal policy, or global indicators to improve prediction accuracy.

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