# Forecasting of Inflation Rates Based on Macroeconomics Factors Using Adaptive Neuro-Fuzzy Inference System (ANFIS) Methods

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## ABSTRACT

Inflation stability becomes very important because it relates to the economic growth that will have an impact on improving the welfare of society. Therefore, controlling inflation will prevent a high and an unstable inflation that gives negative impact on the economic conditions. This study aims to develop appropriate models for inflation forecasting. The approaches used is ANFIS. Based on the results obtained, using the data of general inflation and inflationary spending seven groups period 2010-2022, showed that the ANFIS model that has been obtained shows that by using two membership functions, to model general inflation, it is generated by the transfer function model with the input money supply, one month before Eid Al-Fitr, the month when there is Eid al-Fitr, and the increase in fuel prices as influential variables.

**Keywords:** ANFIS; inflation; forecasting; macroeconomic.

## 1. Introduction

Inflation is a general and continuous increase in prices. An increase in the price of just one or two goods cannot be called inflation unless the increase is widespread or results in an increase in prices for other goods (Al Makhrus and Priyadi, 2022). The causes of inflation have been studied by several researchers, including research conducted by Widiarsih and Romanda (2020) regarding the impact of exchange rate depreciation and money supply growth on inflation. Jumiati (2022) states that the inflation rate in Indonesia is influenced by the SBI interest rate. Ningsih and Andiny (2018) researched that inflation is not only influenced by input (the amount of money in circulation) but there is also intervention from increases in fuel prices, basic electricity tariffs and salaries of civil servants. National inflation is divided into general inflation for all commodities and inflation based on seven expenditure groups based on each commodity.

In several incidents, the national inflation value always fluctuates with a tendency to increase during the Eid al-Fitr holiday (Nasution et al., 2021). This is due to an increase in the prices of goods on the market just before the Eid al-Fitr holiday. The increase in prices of goods will usually continue until the effects of the Eid al-Fitr holiday are over so that market prices will return to normal.

Inflation stability is very important because it is related to economic growth which will have an impact on increasing people's welfare. When there is high inflation, prices will continue to creep up and cause people to be unable to buy the goods they need (Luwihadi and Arka, 2017). Therefore, the importance of controlling inflation will prevent inflation from rising too high and unstable which will have a negative impact on the socio-economic conditions of Indonesian society.

There are many methods that can be used to model time series data, but their use must be adjusted to the characteristics and variables of the data in order to obtain the best model. This research aims to model inflation using macroeconomic factors as predictor variables, namely money supply and interest rates. Apart from that, it also includes intervention events that are thought to have an influence, namely the increase in the basic electricity tariff, the increase in fuel prices, and the increase in salaries for civil servants as well as including calendar variations, namely Eid al-Fitr. There has been no evaluation of the forecast results, encouraging this research to be carried out using a modern approach (ANFIS) to obtain forecast results on inflation data by looking at the best level of accuracy and will be used as a basis for forecasting several periods into the future. Thus, it is hoped that this research can provide input for Bank Indonesia as a consideration for making monetary policy.

## 2. Literature Review

Attention to the case of inflation in Indonesia has become so great since Indonesia adopted an inflation target system or what is usually called inflation targeting in 2000. This system is one of the monetary policies used to control inflation so that it remains stable by announcing to the public the inflation target. want to achieve in the next few periods. With the announcement to the public, there is an implied statement that stable inflation is the main goal of monetary policy. Dwihapsari et al., (2021) stated that inflation modeling and forecasting is needed for a number of reasons. This is important from the perspective of poverty alleviation and social justice because inflation will reduce the income value of people with fixed incomes. Inflation also causes relative price distortions because some prices adjust more slowly than others. These distortions cause efficiency losses and reduce the productive base of the economy.

There are several ways to predict inflation values in Indonesia, for example using intervention models and calendar variations (Setyaningsih, 2010). The calendar variation model is used to forecast data based on seasonal patterns with periods of variation (Karomah, 2014). Another research regarding the prediction of inflation values by including economic factors, namely world oil prices and money supply using the autoregressive distributed lag (ARDL) method, was carried out by Islamiyah (2013). Research on the relationship between inflation and interest rates, the rupiah exchange rate against the dollar, and the composite share price index was carried out by Suharsono (2012). Meanwhile, methods have also been developed abroad to predict inflation values, namely in Nakamura (2005) which uses the neural network method as a method for forecasting inflation in several countries (USA, Japan and several cities in Europe). Apart from that, other research was also conducted by Maurice (2013) who used the seasonal ARIMA

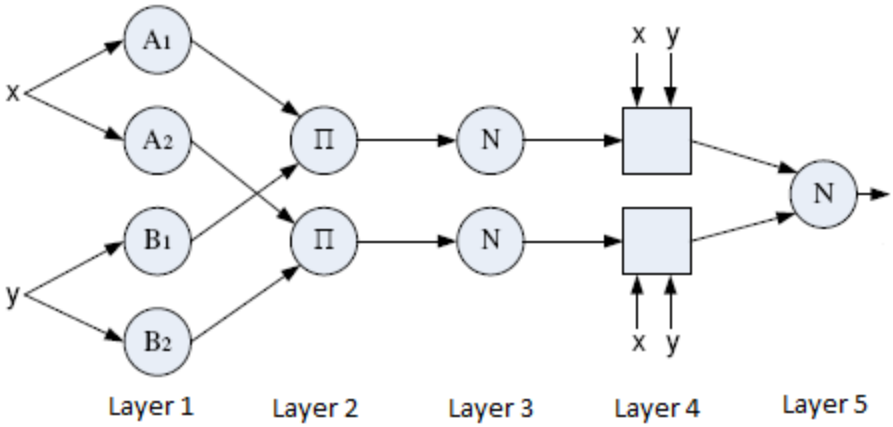
method and the Holt-Winters method as an approach method for predicting inflation values in Ghana.

Modern forecasting methods have developed very rapidly over the last few decades, which has resulted in several modern methods emerging that offer high accuracy, good validity and several advantages including ease of calculation. One way is to use the Adaptive Neuro Fuzzy Inference System or ANFIS approach (Wijayanto, 2012) and Fariza et al (2007). Adaptive Neuro Fuzzy Inference System is a combination of two systems, namely a fuzzy logic system and an artificial neural network. The neuro-fuzzy system is based on a fuzzy inference system that is trained using a learning algorithm derived from artificial neural network systems. Thus, neuro-fuzzy systems have all the advantages of fuzzy inference systems and artificial neural network systems. ANFIS is an architecture that is functionally the same as the Sugeno fuzzy model. The ANFIS architecture is also the same as an artificial neural network with a radial function with certain limitations. It could be said that ANFIS is a method in which a learning algorithm is used to adjust the rules on a set of data. ANFIS also allows rules to adapt (Kusumadewi 2002).
ANFIS is a combination of Artificial Neural Network (ANN) and Fuzzy Inference (FIS). Wijayanto (2012) and Fariza et al (2007) state that Fuzzy logic has advantages in modeling qualitative aspects of human knowledge and decision-making processes by applying rule bases, while ANN has advantages in regarding patterns, learning and practicing in solving problems. problems without mathematical modeling, ANN can also work based on historical data input to it and can predict future events based on this data.

## 3. Research Methodology

Adaptive Neuro-Fuzzy Inference System (ANFIS) is a combination of fuzzy inference system mechanisms described in a neural network architecture. ANFIS is a method that is often used for prediction or diagnosis. ANFIS is a combination of two systems, namely neural network and fuzzy logic. Neural Network is a structure that imitates the existence of nerve cells (neurons) as in the human brain. The artificial nervous system makes it easy to classify an object. Fuzzy logic is a way to map an input space into an output space, in which there is fuzzy set theory which is basically an extension of classical set theory. Based on system input, Fuzzy logic is the use of membership functions to determine how much a predicate fulfills a function expressed in "if - then" which provides convenience by not requiring mathematical analysis for modeling.
The ANFIS method consists of 5 layers, each layer has a different treatment (Fatkhurrozi et al, 20212).

Figure 1. Layers in the ANFIS Method




Layer 1 is the data fuzzification process. Each node i in this layer is an adaptive node with node function:

$$O_{1,i} = \mu A_i(x) \quad \text{for i = 1,2, or}$$

$$O_{1,i} = \mu B_{i-2}(y) \quad \text{for i = 3, 4}$$

The parameter membership function of Ai can be approximated by a function

$$\mu A_i(x) = \frac{1}{1+\left[\left(\frac{x-c_i}{a_i}\right)^2\right]^{b_i}}$$

where {ai,bi,ci} is a set of parameters. The parameters in this layer are called premise parameters.

Layer 2 is also called the product layer. Each node in this layer is labeled Π, is non-adaptive (fixed parameters) and has an output in the form of a multiplication of all incoming signals. Each node's output states the degree of activation of the fuzzy rule. In general, several T-norm operators that can express fuzzy AND logic can be used as node functions in this layer.

Layer 3 is referred to as the normalization layer. Each node in this layer is labeled N, also non-adaptive. Each node displays a normalized activation degree of the form:

$$O_{3,i} = \frac{w_i}{w_1 + w_2}$$

If more than two rules are formed, the function can be expanded by dividing wi by the total number w for all rules.

Layer 4 or Defuzzification layer. The nodes in this layer are naturally adaptive. The defuzzification output of this layer is calculated in the form:

$$O_{4,i} = O_{3,i}\left(\alpha_{4,i} = O_{3,i}\left(\alpha_i x\right) + \beta_i y + \gamma\right)$$

with αi, βi and γi are linear consequent parameters of the suitability of node i.
Layer 5 or Total Output layer. A single node in this layer synthesizes the information sent by layer 4 and returns the entire output using the following fixed function:

$$O_{5,i} = \frac{\sum w_i y_i}{\sum w_i}$$

The ANFIS implementation process used in the output estimation process (inflation rate) has the following sequence (Taib and Ibrahim, 2012).

- Time Series Data Preparation
  In preparing time series data, the time series data is formed into a matrix that has an input-output pattern in the columns
- Setting and Fuzzy Model Formation
  This stage is the stage of determining the type of membership function, the number of membership functions for each input and the data being trained. From the results of setting the fuzzy parameters, a fuzzy model will then be formed. At this stage, a Sugeno fuzzy model will be formed with previously determined parameters.
- Learning Adaptive Neuro Fuzzy
  At this stage, training data will be studied on adaptive neuro fuzzy which will produce an output matrix, then this matrix will be used for the estimation process.
- Output Adaptive Neuro Fuzzy
  The output from adaptive neuro fuzzy will be a graph containing curves from actual data and neuro fuzzy predicted data, so that from the results of the data learning process a model will be found to estimate the output by simply changing the parameters in the membership function.

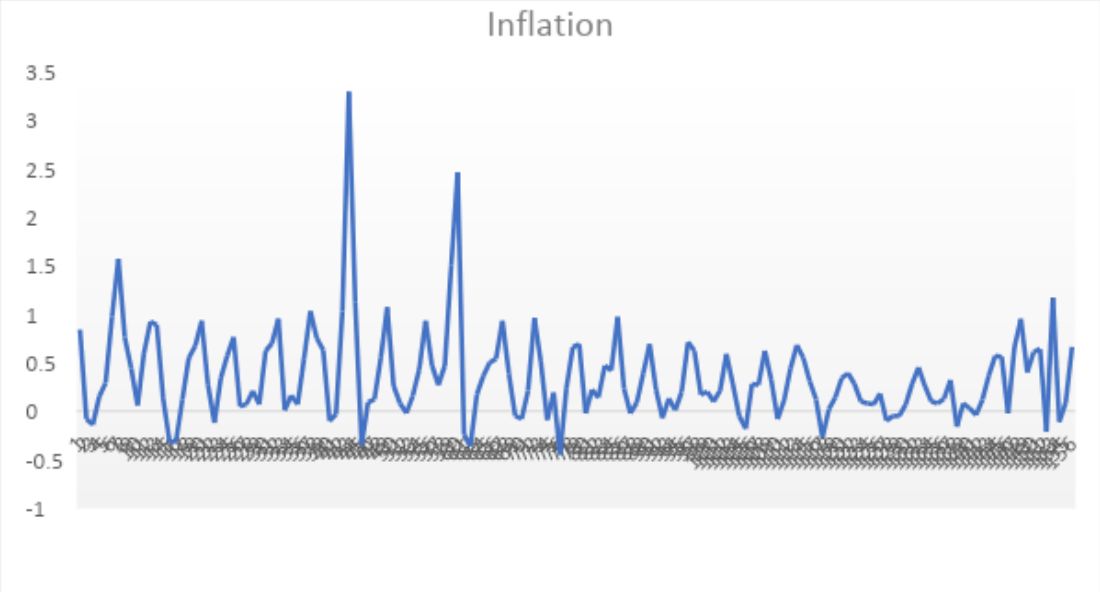
## 4. Results

Before carrying out analysis to answer the research objectives, the first step is to prepare the data, namely determining the data period that will be used. The period used in this research is January 2010 to December 2022. The data is divided into two, namely the training data used is data from January 2010 to December 2021, while data from January to December 2022 is used as testing data. The next step is to carry out descriptive statistical analysis of the output variables and input variables with the aim of describing the characteristics of each variable during the period January 2010 to December 2022.
The characteristics of each variable can be determined through descriptive statistical analysis so that information that is easy to understand can be obtained, where the data used is data consisting of eight variables, namely general inflation and seven inflations based on expenditure groups which include the foodstuffs group, ready-made food group, drinks, cigarettes and tobacco, housing, water, electricity, gas and fuel groups, clothing groups, health groups, education,

recreation and sports groups, as well as transportation, communication and financial services groups.

Figure 2 shows that there are several outliers in each inflation group. This outlier is due to the months in which the Eid al-Fitr holiday occurs each year. National inflation values always fluctuate with a tendency to increase during the Eid al-Fitr holiday. This is due to an increase in the prices of goods on the market just before the Eid al-Fitr holiday. The increase in prices of goods will usually continue until the effects of the Eid al-Fitr holiday are over so that market prices will return to normal. Overall, there is no visible influence of time on each month from year to year, and there is no increasing or decreasing trend.
The presence of a large number of outliers could be one of the causes of abnormalities in inflation data. At this stage, forecasting national general inflation along with seven expenditure groups uses a non-linear method, namely ANFIS. Forecasting using the ANFIS method. Forecasting using the ANFIS method consists of two main parts, namely the input and output parts. Through data pairs, each of which acts as input and output, the ANFIS procedure will form an appropriate model so that it can be used to forecast several stages into the future.

Figure 2. Monthly Inflation Rate Pattern 2010 – 2022




Forecasting using the ANFIS method is divided into 3 processes, namely: initial initialization process, learning process, and forecasting process. Determination of the input period and training period is carried out during initial initialization where each input period has a different pattern. The data used for the training process consists of input data, ANFIS parameters, and test data during the ANFIS training period.

### *4.1 Training Phase*

Table 1 provides information on the influence of learning rate on epochs where the smallest RMSE and MSE at 0.09 are 0.4457 and 0.1987.

Table 1. Effect of learning rate on epoch

| η | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 |
|---|---|---|---|---|---|---|---|---|---|
| RMSE | 0.9134 | 0.8812 | 0.7381 | 0.6901 | 0.6125 | 0.5562 | 0.5129 | 0.4971 | 0.4457 |
| MSE | 0.7782 | 0.7271 | 0.6912 | 0.5991 | 0.5297 | 0.4192 | 0.2416 | 0.2109 | 0.1987 |
| epoch | 23 | 11 | 9 | 9 | 4 | 4 | 3 | 3 | 3 |

It can also be explained that the greater the learning rate, the faster it will converge so that the epoch value required is not so large and conversely, by using a small learning rate, the epoch value required will be greater to achieve the smallest MSE and RMSE values, but convergence that is too fast can result in weight What is obtained is not the global optimum value so that the forecast results tend to be inaccurate.

### *4.2 Testing Phase*

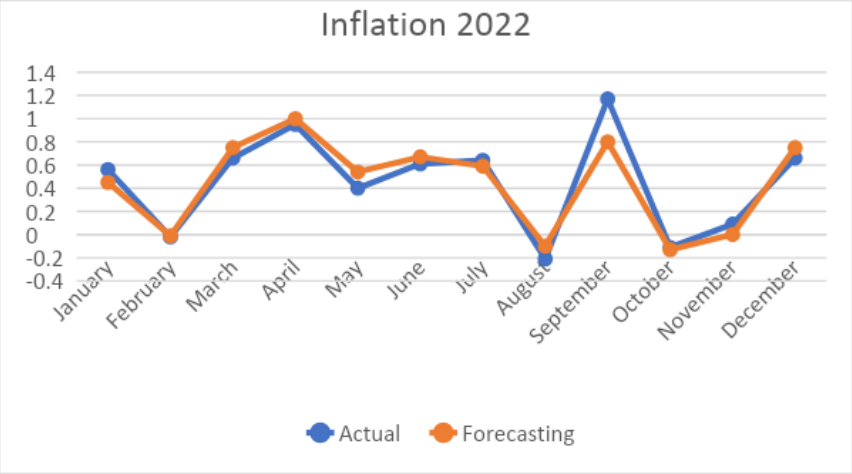
At the training stage, information has been obtained that the greater the learning rate, the faster it will converge so that the required epoch value is smaller and vice versa. To predict the inflation rate using the learning rate, 0.09 and epoch 3 are used to obtain a normalized prediction of the inflation rate for 2022 in Table 2 and Figure 3.

Table 2. Inflation rate in 2022 actual value and ANFIS forecast

| **Month** | **Actual** | **Forecasting** |
|---|---|---|
| January | 0.56 | 0.45 |
| February | -0.02 | -0.01 |
| March | 0.66 | 0.75 |
| April | 0.95 | 1 |
| May | 0.4 | 0.54 |
| June | 0.61 | 0.67 |
| July | 0.64 | 0.59 |
| August | -0.21 | -0.1 |
| September | 1.17 | 0.8 |
| October | -0.11 | -0.13 |
| November | 0.09 | 0 |
| December | 0.66 | 0.75 |

Based on the results obtained, it can be concluded that the error rate using the ANFIS method for forecasting the inflation rate in 2022 is 1.926% with the largest error value occurring in September 2022, namely 10.51%.

Figure 3. Inflation rate in 2022 actual value and ANFIS forecast results




The inflation rate in the months approaching Eid al-Fitr (March and April) can be predicted accurately, while the forecasting error that occurred in September was more due to the fluctuating inflation rate.

## 5. Discussion

The negative difference between forecast data and actual data indicates that the estimated results are too large for actual inflation. Meanwhile, a positive difference indicates greater actual inflation. The largest negative difference occurred in May, this could occur due to inflationary pressure caused by the month after Eid al-Fitr celebrations. The positive difference that occurred in September was triggered by disruptions on the supply side, especially food ingredients, which increased sharply due to weather anomalies at both global and domestic levels. This condition triggered a spike in food commodity prices on the global market and at the same time affected the domestic market. Staple commodities such as rice and various spices contributed quite significantly to price increases.

From the process of forecasting the inflation rate using the Adaptive Neuro Fuzzy Inference System (ANFIS), several things that influence the resulting RMSE value are as follows:

- The amount of training data used greatly influences the RMSE value. The more training data, the smaller the RMSE produced and the greater the level of accuracy produced in the forecasting process.
- The learning rate value does not have a significant influence on the RMSE value and the level of forecasting accuracy if the amount of training data used is small. The effect will appear significant if the training data used is large. The larger the training data, the more influential the learning rate value is.

## 6. Conclusion

The ANFIS method can be used to build a model for forecasting the rate of inflation in Indonesia. This model was built by experimenting with various combinations of structures and parameters to produce a model with the lowest MAPE value. Overall, ANFIS is able to carry out training on data and model the behavior of input-output relationships well.

We hope that research using the same models and methods will continue to be developed in order to obtain perfect results. There is a need for further research and analysis regarding other variables that may have an influence on increasing the rate of inflation in a country.

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