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Vector Autoregressive X (VARX) Modeling for Indonesian Macroeconomic Indicators and Handling Different Time Variations with Cubic Spline Interpolation

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ABSTRACT

This study discusses data handling that has different time variations (for example, data available in quarterly form but the desired data is monthly) in this case the GDP variable in the quarter series, while the other five variables use monthly series, whereas in multivariate analysis the data condition must be the same, then an approach is taken to reduce monthly data from quarterly data using the interpolation method. Therefore, before conducting the VARX analysis the author interpolated GDP data from the quarter to monthly by interpolation. After the data is ready, VARX modeling of the exchange rate, economic growth (GDP), interest rates on Bank Indonesia Certificates (SBI), and inflation as endogenous variables and US interest rates (FFR) and US inflation as exogenous variables. The purpose of this study is to implement and evaluate the performance of Cubic Spline interpolation methods for time series data that have different time variations. Build VARX models of exchange rates, economic growth (GDP), SBI interest rates, and inflation based on US interest rates (FFR) and US inflation with the best models. Meanwhile, the interpolation method used by researchers to estimate the monthly value of the GDP variable based cubic spline interpolation. Based on the AIC value of the smallest VARX model obtained at 240.6668 so the best model obtained is the VARX (4.0) model.

Keywords : Cubic Spline Interpolation, Vector Autoregressive X (VARX)

I. INTRODUCTION

Indicators of Indonesia's economic stability can be seen from the macro conditions. As for these conditions, for example, the economic growth rate of 5.1% in 2017, slightly increased compared to 5.0% in 2016 (BCA 2017). Other indicators, namely the rupiah exchange rate against US dollars in 2018 continued to rise until October 2018 reaching Rp. 15,227, while in 2017 the value was relatively stable, even though it had experienced pressure in the second semester of 2017. The rupiah exchange rate was closed at Rp 13,555 per 1 US dollar at the end of 2017, compared to Rp 13,473 per 1 US dollar at the end of 2016. Meanwhile, inflation remained within the government's target range and was recorded at the level of 3.6% in 2017 compared to 3.0% in 2016 (BCA 2017) .

In general, in order to adjust the dynamics of the global economy and maintain domestic economic stability, BI made adjustments to interest rates on the movement of US interest rates or the Federal Funds Rate (FFR). According to Retnasih et al. (2016) the openness of the Indonesian economy and the high level of dependence on developed countries, resulting in the planning and implementation of monetary policy cannot run independently. In each policy setting, BI also considers the fluctuations in the condition of the US economy. This is related to the flow of funds in and out due to trade and financial transactions carried out. This flow of funds will affect

the exchange rate, inflation which will ultimately affect Indonesia's economic growth. Therefore we need a model to predict Indonesia's macroeconomic conditions going forward through forecasting future economic conditions through indicators that have the potential to determine the ups and downs of economic conditions such as conditions of economic growth, SBI interest rates, inflation, and the rupiah exchange rate against the dollar. The analysis that can be used to make predictions is time series analysis. The Vector Autoregressive X (VARX) model is a time series model to model several endogenous variables that are interconnected influenced by the previous time and there are exogenous variables that influence the endogenous variable. According to Fung (2006) and Aida et al. (2015) data handling that has different time variations in time series analysis can be approached using the interpolation method.

This study discusses data handling that has different time variations (for example, data available in quarterly form but the desired data is monthly) in this case the GDP variable in the quarter series, while the other five variables use monthly series, whereas in multivariate analysis the data condition must be the same, then an approach is taken to reduce monthly data from quarterly data using the interpolation method. Therefore, before conducting the VARX analysis the author interpolated GDP data from the quarter to monthly by interpolation. After the data is ready, VARX modeling of the exchange rate, economic growth (GDP), interest rates on Bank Indonesia Certificates (SBI), and inflation as endogenous variables and US interest rates (FFR) and US inflation. The purpose of this study is to implement and evaluate the performance of Cubic Spline interpolation methods on time series data that have different time variations. Build the best models of VARX models based exchange rates, economic growth (GDP), SBI interest rates, and inflation based on US interest rates (FFR) and US inflation as exogenous variables.

II. METHODS

A. Data

The data used in this study are secondary data taken from related institutions or agencies such as the annual report, Indonesian Economic and Financial Statistics (SEKI), Badan Pusat Statistik (BPS) of Indonesia, the Fed, and Data Inflation. Data in monthly and quarterly periods from January 2012 to April 2017 (64 data). The data is divided into two parts, namely training data from January 2012 to October 2016 as many as 58 data and testing data from November 2016 to April 2017 as many as 6 data.

The variables used in this study are macroeconomic indicators, including the rupiah exchange rate (monthly), inflation (monthly), GDP (quarterly), SBI interest rates (monthly), US interest rates (monthly), and US inflation (monthly).

B. The Stage of Analysis

The data analysis stages used are as follows:

1. Exploring data.

Plot on each exchange rate variable, economic growth (GDP), SBI interest rate, and inflation to see the distribution of the data.

2. Pre-processing data.
   - Before the data is ready for processing, pre-processing data is carried out by applying Cubic Spline interpolation methods for different time variations, it obtained using the formula:

$$F(x) = a_{n-1}(x - x_{n-1})^3 + b_{n-1}(x - x_{n-1})^2 + c_{n-1}(x - x_{n-1}) + d_{n-1}\ ,x_{n-1} \leq x \leq x_n$$

(Anton 1988).

This process uses the help of software R with the package zoo and Ml metrics.

   - Estimate the monthly GDP value.

3. Checking Stationary Data

Stationary examination of the data can be seen from the plot between the values of observation and observation. If the use of this plot is deemed insufficient, a formal test can be carried out using the

Augmented Dickey-Fuller (ADF) test to check the average stationary and Levene test to check the range stationary.

4. Build VARX Model

   a. VARX modeling is done by estimating simultaneously the VAR model and exogenous variables indicated to influence the model.

   The general form of VARX (p, s) is (SAS 2014):

$$\boldsymbol{y_t} = \boldsymbol{\phi}_0 + \boldsymbol{\phi}_1 \boldsymbol{y}_{t-1} + \cdots + \boldsymbol{\phi}_p \boldsymbol{y}_{t-p} + \boldsymbol{\beta} \boldsymbol{x}_t + \boldsymbol{\varepsilon}_t$$

   b. Diagnostic test of the VARX model which includes:

- Checking residual norms using q-q plot.
- Checking residual white noise by looking at Matrix Partial Autocorrelation Function (MACF) results.
- Proof of minimum Akaike Information Criterion (AIC) value in lag 0. AIC is obtained using the formula:

$$AIC(p) = \ln\left(\left|\hat{\Sigma}_p\right|\right) + \frac{2m^2 p}{n}$$

   i. Get the best models of VARX models based exchange rates, economic growth (GDP), SBI interest rates, and inflation based on US interest rates (FFR) and US inflation as exogenous variables.

5. Calculate the mean absolute percentage error (MAPE) value of the VARX models using testing data. MAPE is obtained the formula:

$$\text{MAPE} = \frac{\sum_{t=1}^{N} \left| \frac{y_t - \bar{y}_t}{y_t} \right|}{N} X\ 100\%$$

III. RESULTS AND DISCUSSION

A. Data Exploration

The data used to see the data pattern is the data of the last three years (Year 2015-2017). The time period of the variables varies. This stage wants to see the data pattern of macroeconomic indicators used before pre-processing the data. Indonesia's GDP growth in the last three years has fluctuated, and in 2017 the growth rate continues to increase continuously every quarter. Indonesia's inflation rate is at the end of 2017 at the level of 0.71. The rupiah exchange rate against the USD until finally closed with a value of Rp. 14,710 in August 2017, this means that the last three years the rupiah exchange rate has continued to increase which indicates that the rupiah has weakened in the past decade. Furthermore, SBI interest rates experienced a downward trend, this indicates that SBI interest rates are getting weaker in the last three years.

B. Pre Processing Data

The pre-processing data stage that is carried out includes handling data that has different time variations, in this study the data is GDP with a period of time in the form of quarterly data with cubic spline interpolation method to estimate the monthly value of the GDP variable.

C. VARX Modeling with Cubic Spline Interpolation Results

Stationarity Test

Stationary tests can use ACF and PACF plots, view data plots, and perform formal tests to ensure data stationary using the Dickey-Fuller unit root (DF) root test. The results of the DF test showed that there were variables that were not stationary, so that they were differed once, then viewed the ACF and PACF plots again and the formal results of the Dickey-Fuller unit roots. As for there are variables that are not stationary in the average, it is done differencing 1 time and then testing stationarity again so that all data is stationary.

After doing differencing 1 time, for the exchange rates variable the value of the Prob is obtained. amounting to 0.0010 <0.05. so it can be concluded that the exchange rates is already stationary. The variable SBI interest rate is Prob. equal to 0.001 <0.05 so it can be concluded that the SBI interest rate is indeed stationary. Then in the GDP variable the value of the Prob. equal to 0.001 <0.05 so it can be concluded that GDP is stationary. Furthermore, the

inflation variable has met the standard conditions in the average because of the value of the Prob. 0.0010 <0.05 so it was concluded that inflation was already stationary. While the US interest rate variable is the Prob value. equal to 0.001 <0.05 so it can be concluded that US interest rates are still not stationary. US inflation variable Prob value. equal to 0.001 <0.05 so it can be concluded that US inflation is stationary.

Build VARX Model

Before determining the VARX model, the appropriate lag selection is required through VAR analysis. Identify the appropriate lag seen from two factors, namely the significance of lag based on Matrix Autocorrelation Function (MACF) and Matrix Partial Autocorrelation Function (MPACF), and the AIC value on the lag. The selected lag value is ultimately a significant lag value and has the smallest AIC value. It was obtained that the smallest AIC value from the VAR analysis using the exchange rates variable, Inflation, SBI interest rate, and GDP, namely the AIC value in the lag 4 amounted to -7.74043 and lag 5 amounting to -9.59425 so the best model was VARX (4, x). Besides because the AIC value is not much different, the chosen lag 4 is also due to consideration of the number of lags that will be included in the model. The use of a longer lag will result in more lost degrees. Then after overfitting from VARX (1,1) to VARX (4,3), the AIC values of each model are obtained as follows:

TABLE I

OVERFITTING VARX MODEL

VARX Model	AIC value	VARX Model	AIC value
VARX (4,3)	248.5332	VARX (2,3)	303.3735
VARX (4,2)	250.6919	VARX (2,2)	301.335
VARX (4,1)	247.1171	VARX (2,1)	293.9603
VARX (4,0)	**240.6668**	VARX (2,0)	288.1536
VARX (3,3)	274.4197	VARX (1,3)	368.9927
VARX (3,2)	271.6757	VARX (1,2)	368.3138
VARX (3,1)	265.0039	VARX (1,1)	356.6725
VARX (3,0)	257.013	VARX (1,0)	348.9735

Based on the AIC value of the VARX model estimated in Table 1 above, the smallest AIC value is obtained at 240.6668 so the best model obtained is the VARX (4.0) model.

D. Diagnostic Test of The VARX Model

The diagnostic test of the VARX model includes checking the q-q plot to find out whether each residual has spread normally, the residual q-q plot on the VARX model has followed the normal distribution. This is indicated by residual plots that spread almost along the diagonal line and follow the direction of the diagonal line. And Kolmogorov-Smirnov's formal test shows that the normal exchange rates variable at $\alpha = 0.05$, while the inflation variable, SBI interest rate and normal GDP at $\alpha = 0.01$. Thus, it can be said that each residual has followed the normal distribution. Next, check the white noise multivariately through the MACF and Portmanteau results from the residual test. The MACF results show the dominant symbols appearing from lag 1 until lag 10 is (.). This indicates that the model is very good and there is no correlation between residuals, so the residuals are white noise. Then the Portmanteau test was carried out to confirm the conclusions. Residual is white noise if the p-value is greater than the real level (5%). Based on the results it was obtained that almost until the 12th lag had a p-value value that was greater than the real level (5%), this indicated that the side was already white noise.

E. Evaluation of VARX Model

Evaluation of the results of the VARX model is done by calculating the MAPE value for the forecast results of testing data for exchange rates variables, inflation, SBI interest rates and GDP. The MAPE value is variable exchange rates (0.01892163), Inflation (9.02037), SBI interest rate (0.027025) and GDP (0.021403). Each variable has a MAPE value of less than 10%, so it is concluded that the VARX (4.0) model has excellent forecasting capabilities. So that the VARX (4.0) model can be used for exchange rates forecasting, inflation, SBI interest rates and GDP in the coming period.

IV. CONCLUSION

In this study it can be concluded that the interpolation method for estimating the monthly value of the GDP variable is cubic spline interpolation. While the best model built is the VARX (4.0) model which has excellent forecasting ability to predict the exchange rates, Inflation, SBI and GDP variables in the coming period.

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