BAREKENG: Journal of Mathematics and Its Applications
March 2024 Volume 18 Issue 1 Page 0341–0348
P-ISSN: 1978-7227 E-ISSN: 2615-3017
https://doi.org/10.30598/barekengvol18iss1pp0341-0348

APPLICATION OF THE NEURAL NETWORK AUTOREGRESSIVE (NNAR) METHOD FOR FORECASTING THE VALUE OF OIL AND GAS EXPORTS IN INDONESIA

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Article History:

Received: 31st August 2023
Revised: 6th December 2023
Accepted: 5th January 2024

Keywords:

Forecasting;
Neural Network
Autoregressive;
Oil and Gas Export.

ABSTRACT

Indonesia is one of the countries with the most diversity and abundant natural resources, consisting of many commodities, and has enormous trade potential with other countries. The success of economic activity in a country can be measured by the amount of economic growth that occurs in the country. A recession is when a country's economic condition is getting worse. Meanwhile, a recession in Indonesia is expected to occur in 2023. In a 2022 news issue written by the editorial team, tirto.id said that some experts say that if 2023 is a recession, the cause is a spike in inflation from the impact of the Russia-Ukraine conflict. It is known that the value of oil and gas exports affects the Indonesian economy. Any increase in the value of oil and gas exports will be followed by an increase in economic growth and vice versa. However, over time, the value of oil and gas exports has decreased every year. Therefore, forecasting the value of oil and gas exports is needed so that the country's economic sector development strategy can be on target. In addition, oil and gas export forecasting is also needed to determine the distribution of goods exports that must be carried out. In this study, we forecast the value of oil and gas exports using the neural network autoregressive (NNAR) method. This method was chosen because there is no assumption of normality of the residuals and white noise like in autoregressive models. From the NNAR method, the best model results are obtained, namely NNAR (2,3) with a MAPE value of 11.75640%, which means that this model has good forecasting performance.

How to cite this article:

T. P. Junita and M. D. Kartikasari., "APPLICATION OF THE NEURAL NETWORK AUTOREGRESSIVE (NNAR) METHOD FOR FORECASTING THE VALUE OF OIL AND GAS EXPORTS IN INDONESIA," *BAREKENG: J. Math. & App.*, vol. 18, iss. 1, pp. 0341-0348, March, 2024.

Journal homepage: *https://ojs3.unpatti.ac.id/index.php/barekeng/*
Journal e-mail: *barekeng.math@yahoo.com; barekeng.journal@mail.unpatti.ac.id*

Research Article · Open Access

1. INTRODUCTION

Indonesia is one of the countries with the most diversity and abundant natural resources, consisting of many commodities, and has enormous trade potential with other countries. The rate of economic growth in a nation can serve as a gauge of that nation's economic success. If economic growth develops positively, it will have a positive impact and cause good results for the welfare of society and the country [1]. A recession [2] is a country's deteriorating economic condition. Meanwhile, a recession in Indonesia is expected to occur in 2023. In a 2022 news issue written by the editorial team, tirto.id said that some experts say that if 2023 is a recession, the cause is a spike in inflation from the impact of the Russia-Ukraine conflict. If there is indeed a recession in 2023, it will greatly affect the activities of various fields of a country's exports. The impact of a recession can causes the value of exports to fall because producers fail to get funds to produce products.

Exports are an important part of a country's economy; the higher a country's export earnings, the greater the positive influence on the economy that the country will have [3]. However, when imports are greater than exports, it will cause a deficit in the trade balance; otherwise, if exports are greater than imports, the trade balance will show a surplus [4]. Export-import activities play an important role in the economic activity of the country [5]. The lack of foreign exchange reserves owned by a country is the most frequent phenomenon caused by higher import values than export values [6]. Thus, Indonesia's active participation in international trade is expected to be able to support the Indonesian economy. The oil and gas sector, along with all supporting sectors, can contribute up to 62.67% of gross domestic product (GDP). This oil and gas sector has a role as a driving sector for economic growth [7].

Based on sources from the Central Statistics Agency's website, the value of oil and gas exports in Indonesia experienced a fluctuating decline, with the worst condition being in May 2020, in line with the increasing number of COVID-19 spreads in Indonesia. As a result of these conditions, forecasting the value of oil and gas exports is one of the appropriate ways to serve as a guide and tool to help the government in planning, making decisions, and making policies in the future.

Forecasting estimates something that has yet to happen; this forecasting aims at the decision-making process. In forecasting, several methods are often used, namely ARIMA [8], exponential smoothing [9], moving averages [10], and others. However, in this study, researchers use the Neural Network Autoregressive (NNAR) method [11]. The NNAR model is a feedforward neural network model that uses single-variable data with a p-lag at the input layer. The study by As'ad and Farida claimed to have used this approach because it took into account the absence of residual normality and white noise assumptions found in autoregressive models [12]. From this background, researchers will conduct research regarding forecasting using the NNAR method with a case study of Indonesia's oil and gas export value data for 2009-2022. This research is very necessary so that the country's economic sector development strategy can be right on target and to determine the large distribution of goods exports that must be carried out.

2. RESEARCH METHODS

In this study, the data used is secondary data obtained from the Central Bureau of Statistics. The data is the value of Indonesia's oil and gas exports from January 2009 to December 2022 in millions of US dollars.

This research consists of several stages. The first is to collect secondary data in the form of data on the value of oil and gas exports in Indonesia. Next, do a descriptive analysis to see the general description of the data. Then, determine the network input, model identification, and fit the NNAR model. After that, test the best model using the smallest MAPE value. Finally, do forecasting based on the best model that has been selected. The research flowchart is presented in **Figure 1**.

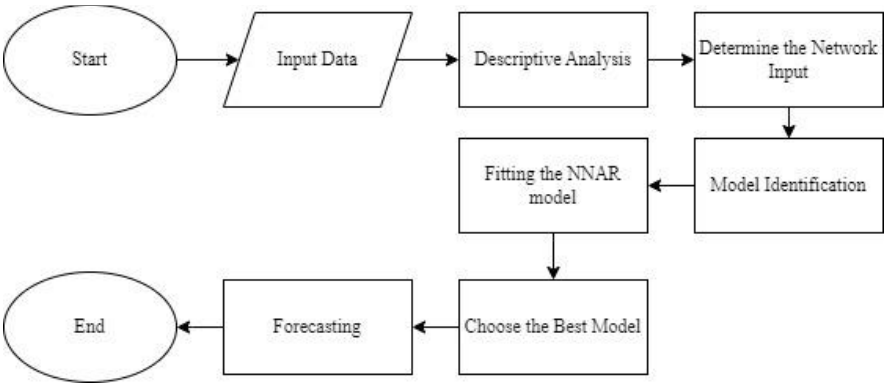

Figure 1. The Research Flowchart

2.1 Neural Network Autoregressive

Neural Network Autoregressive (NNAR) was introduced in 2018 by Hyndman and Athanasopoulos as their application program with the R package in the "Forecast" package with the *nnetar* function. The NNAR model is a feedforward neural network model that uses single-variable data with p lag at the input layer. This model was created for a feedforward neural network with one hidden layer and denoted by NNAR (p, k) with k stating the number of neurons in the hidden layer and p stating lagged input [13]. The equation of the linkage of output and input models is as follows. [14]

$$y_t = \alpha_0 + \sum_{j=1}^{h} \alpha_j f\left(\sum_{i=1}^{p} \beta_{ij} y_{t-i} + \beta_{0j}\right) + \varepsilon_t. \quad (1)$$

The notation β_{ij} $(i = 0,1,2,\dots,n\,; j = 1,2,\dots,h)$ and α_j $(j = 0,1,2,\dots,h)$ are weight in the model. The notation p is the number of neurons in the input layer and h is the number of neurons in the hidden layer.

This autoregressive neural network uses a single hidden layer, and then the results of weighted linear combinations are modified into artificial neural network output using non-linear functions. The linear combination function can be written as follows. [15]

$$z_j = \beta_{0j} + \sum_{i=1}^{p} \beta_{ij}\, y_{t-i}. \quad (2)$$

The notation $z_j$is the sum function of the bias unit to j on the hidden layer, β_{0j} is the weight of the bias unit to j, β_{ij} is the weight of i the layer of the bias to j, y_{t-i} is the input to i, network activation function is a non-linear function in the form of a binary sigmoid function and is written as follows.

$$f(z) = \frac{1}{1+e^{-z}}. \quad (3)$$

The equation above is a function of z, this sigmoid function is a part of the activation function in the single layer network model.

2.2 Accuracy

1. Aikake's Information Criterion

   One way to find out how good the model selection is is to use the Aikake information criteria. if K is the model parameter and L is the estimated value of the maximum likelihood method. Then mathematically, the AIC equation can be written as follows. [16]

   $$AIC = 2K - 2\ln(L) \quad (4)$$

2. Mean Absolute Percentage Error

The mean absolute percentage error (MAPE) is the average of absolute errors over a certain period multiplied by 100% so that the results obtained are in the form of percentages. The formula for calculating the MAPE value is as follows. [17]

$$\text{MAPE} = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{y_t - \hat{y}_t}{y_t}\right| \times 100\%, \quad (5)$$

where y_t is actual data in period of t, $\hat{y}_t$ is forecasted data in period of t, and n is the number of data period.

The forecasting model performs well when the MAPE value is low. Four levels of the MAPE include highly accurate (<10%), good (10%–20%), reasonable (20%–50%), and inaccurate (>50%), respectively **[18]**.

3. RESULTS AND DISCUSSION

The value of Indonesia's oil and gas exports from January 2009 to December 2022 in millions of US dollars is presented in **Figure 2**.

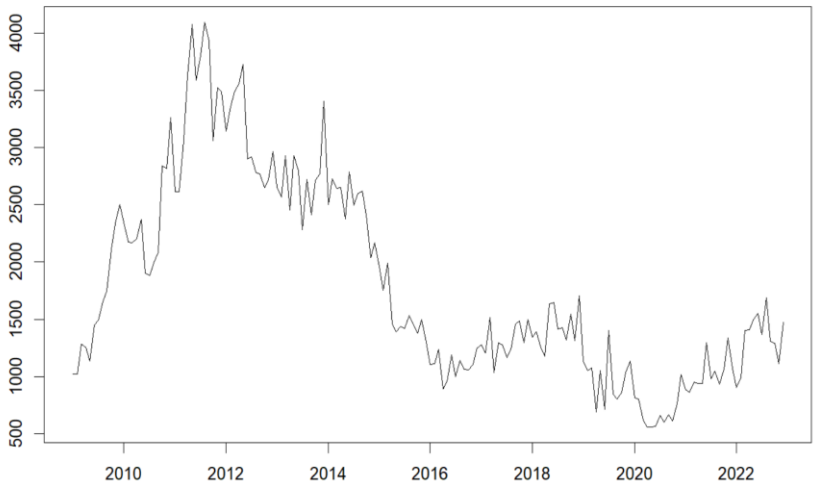

Figure 2. Plot of Indonesia's Oil and Gas Export Value in 2009-2022

Based on the plot in **Figure 2**, it can be explained that the value of oil and gas exports from January 2009 to December 2022 experienced fluctuations and increases. However, if you pay attention to the plot based on the movement of the monthly oil and gas export value, it tends to decrease. In 14 years, namely from 2009 to 2022, the lowest oil and gas export value was in 2020, which experienced a pandemic at that time. In contrast, oil and gas exports were the highest in 2011.

3.1 Network Input for Neural Network Autoregressive

To determine network input, it is carried out using partial autocorrelation (PACF) plots against oil and gas export value data in Indonesia. **Figure 3** is the result of the PACF plot on the variable value of oil and gas exports.

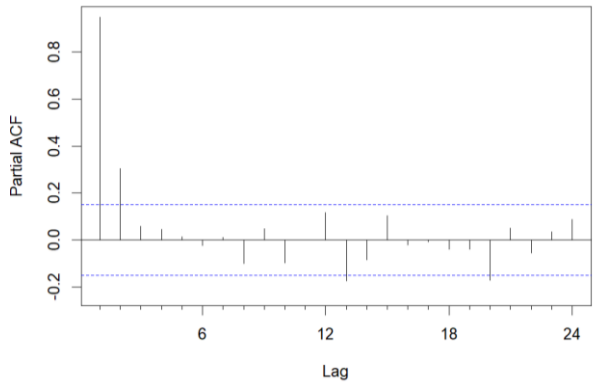

Figure 3. Plot of Partial Autocorrelation

In the determination of autoregressive order for NNAR, the input or predictor used is historical data, and the number of predictors selected is determined by looking at the significant lag in the PACF plot. According to Pontoh et al. [19], this NNAR method does not require assumptions, so there is no transformation or stationarity of the data. Next, determine the network input using the PACF plot shown in Figure 3. There is an autoregressive process at lag 1, lag 2, lag 13, and lag 20. From the four lags, the optimal network input was selected using the smallest AIC, as shown in Table 1.

Table 1. AIC value

Lag	AIC
1	1891.527
2	1873.846
13	1880.361
20	1883.175

From Table 1, it is obtained that the smallest AIC value is in lag 2 and the network input uses lag 2 ($p = 2$).

3.2 Forecasting Using Autoregressive Neural Network Method

Determining the training data model and testing data in the previous PACF plot, it was found that the smallest AIC value is at lag 2, which means the input layer is 2. It then determines the value based on the number of neurons in the hidden layer. To get the value of *k*, that is by calculating from $k = \frac{(p+1)}{2} = \frac{(2+1)}{2} = 2$ (rounded to the nearest integer). From these results, overfitting is carried out using the number of neurons in the hidden layer, as many as 1, 2, and 3.

The forecasting of the value of oil and gas exports in Indonesia from January 2022 to December 2022 will be carried out on three models, namely NNAR (2,1), NNAR (2,2), and NNAR (2,3). The results for forecasting using NNAR (2,1), NNAR (2,2), and NNAR (2,3) are described in Figure 4, Figure 5, and Figure 6, respectively.

Figure 4. Plot of Forecasting Results Using NNAR (2,1)

Figure 5. Plot of Forecasting Results Using NNAR (2,2)

Figure 6. Plot of Forecasting Results Using NNAR (2,3)

In Figure 4, Figure 5, and Figure 6, for the NNAR model, the red line represents the value of oil and gas exports or actual data, while the green line represents the exact value. From the plot, it is known that the green line, or the fitted value, follows the actual data pattern, so it can be said that the model is good for forecasting. However, the testing data does not really follow the actual data for forecasting results.

To determine the performance of the model specifically, it can be seen based on the MAPE value in Table 2.

Table 2. MAPE Value

Model	MAPE (%)	
	Training	Testing
NNAR (2,1)	12.32601	19.10514
NNAR (2,2)	11.93372	17.14513
NNAR (2,3)	11.75640	16.35835

From Table 2, the smallest MAPE value is in the NNAR model (2,3), so this model will be used to forecast the value of monthly oil and gas exports in Indonesia. In the NNAR model (2,3), the MAPE value in the training data obtained is 11.75640%, while for testing data, it is 16.35835%, which means that forecasting is said to be good [14].

3.3 Architecture of Neural Network Autoregressive

The best model from the analysis is NNAR (2,3). The architecture of the model is shown in Figure 7.

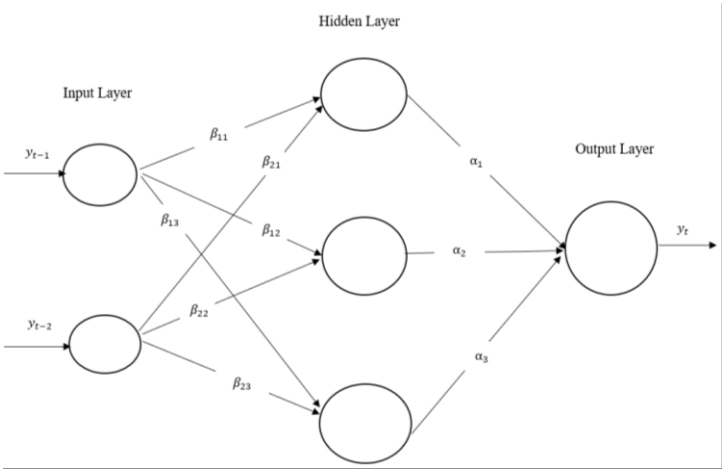

Figure 7. Architecture of NNAR (2,3)

From the architecture in **Figure 7**, there are two input layers, namely y_{t-1} and y_{t-2}. From the input layer to the hidden layer there are six weights taken randomly, namely β_{11}, β_{12}, β_{13}, β_{21}, β_{22} and β_{23}. In the hidden layer, there is a sum function that is subject to bias. From the hidden layer to the output layer, there is subject to an activation function and subject to bias. From the hidden layer to the output layer, there are three weights, namely, α_1, α_2 and α_3. The output obtained is y_t.

3.4 Forecasting Results

The selected forecasting model, the NNAR model (2,3), was then used for forecasting the next 12 periods. The forecasting results are shown in **Figure 8** and **Table 3**.

Figure 8. Plot of Forecasting for the Next 12 Periods

Table 3. Forecasting Results for the Next 12 Periods

Periods	Forecasting Results	Periods	Forecasting Results
January 2023	1299.543	July 2023	1375.681
February 2023	1367.406	August 2023	1380.343
March 2023	1347.736	September 2023	1384.371
April 2023	1363.638	October 2023	1388.280
May 2023	1364.959	November 2023	1391.895
June 2023	1371.613	December 2023	1395.310

The forecasts for the next 12 periods, from January 2023 to December 2023, are shown in **Figure 8** and **Table 3**. According to the forecasting results, the value of oil and gas exports has gradually climbed; in the year 2023, the biggest export value will occur in December and the lowest in January. The forecasting results can be used to estimate monthly changes in the value of oil and gas exports, allowing for precise targeting of the country's economic sector development strategy.

4. CONCLUSIONS

Based on the results and discussion of this research, it can be concluded that the best model for forecasting the value of oil and gas exports in Indonesia is NNAR (2,3), with the MAPE value for training data being 11.75640 and the MAPE value for testing data being 16.35835% with a predicted value in January 2023 of 1299.543, and the following month experienced a not too significant increase. For the future, in the year 2023, forecasts for the value of oil and gas exports have gradually climbed. Forecasting can be used to allow for precise targeting of the country's economic sector development strategy.

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