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Forecasting Indonesian Oil, Non-Oil and Gas Import Export with Fuzzy Time Series

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Abstrak

Indonesia aktif dalam kegiatan ekspor dan impor. Beberapa komoditas yang diperjualbelikan yaitu minyak bumi dan gas, serta bahan pangan dan bahan industri lainnya. Kegiatan ekspor dan impor berperan dalam menentukan kestabilan perekonomian negara dilihat dari neraca perdagangannya. Tercatat dari Badan Pusat Statistik, Indonesia sempat mengalami defisit sebesar 864 juta USD akibat penurunan ekspor pada awal tahun 2020. Berdasarkan keadaan neraca perdagangan, pemerintah perlu membuat kebijakan dalam rangka menjaga kestabilan perekonomian Indonesia. Pengambilan keputusan yang tepat harus didukung oleh informasi yang akurat oleh karena itu melalui penelitian ini akan dilakukan peramalan nilai ekspor impor Indonesia pada sektor migas dan nonmigas untuk periode kedepan menggunakan Fuzzy Time Series (FTS). FTS dipilih sebagai metode peramalan karena mampu meramalkan data real time bebas dengan pola sembarang. Data yang digunakan adalah data nilai ekspor impor sektor migas dan nonmigas tahun 2011-2020. Untuk mengatasi masalah kestasioneran ragam data dan mengurangi nilai kesalahan akan diterapkan transformasi Box Cox. Tahapan penelitian meliputi transformasi data dengan Box Cox, membentuk himpunan semesta dan himpunan linguistik, menentukan panjang interval, fuzzifikasi, membentuk FLR dan FLR, defuzzifikasi dan peramalan. Hasil akhir permalan memperkirakan ekspor impor pada sektor migas tahun 2021 akan mengalami penurunan, sedangkan untuk sektor nonmigas akan berfluktuasi dan mengalami peningkatan dari tahun sebelumnya. Peramalan dengan data hasil transformasi Box Cox lebih akurat dengan nilai MAPE 19,56% dan RMSE 121,52 dibanding peramalan dengan data asli dengan MAPE 74,89% dan RMSE 132,09.

Kata kunci*—Fuzzy Time Series, Transformasi*

Abstract

Indonesia is active in export and import activities. Some of the commodities traded are oil and gas, as well as food and other industrial materials. Export and import activities play a role in determining the stability of the country's economy seen from its trade balance. According to the Central Statistics Agency, Indonesia experienced a deficit of USD 864 million due to a decline in exports at the beginning of 2020. Based on the state of the trade balance, the government needs to make policies in order to maintain the stability of the Indonesian economy. The right decision-making must be supported by accurate information, therefore, through this research, the value of Indonesia's exports and imports will be forecasted in the oil and gas and non-oil and gas sectors for the next period using the Fuzzy Time Series (FTS). FTS was chosen

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as the forecasting method because it is able to predict free real time data with arbitrary patterns. The data used is data on the value of exports and imports of oil and gas and non-oil and gas sectors for 2011-2020. To overcome the problem of stationary data variance and reduce the error value, a Box Cox transformation will be applied. The research stages include data transformation with Box Cox, forming universe and linguistic sets, determining interval length, fuzzification, forming FLR and FLR, defuzzification and forecasting. The final forecast results estimate that exports and imports in the oil and gas sector in 2021 will decline, while for the non-oil and gas sector will fluctuate and increase from the previous year. Forecasting with Box Cox transform data is more accurate with MAPE 19.56% and RMSE 121.52 compared to forecasting with original data with MAPE 74.89% and RMSE 132.09.

Keywords—*Fuzzy Time Series, Transformasi*

1. INTRODUCTION

Indonesia is active in exporting and importing in international trade activities. From the results of its natural wealth, Indonesia is able to export several commodities such as oil and gas as well as various kinds of food from agriculture and fisheries. Meanwhile, for needs that cannot be produced by themselves, the state imports from other countries. Information from the Central Statistics Agency said that at the beginning of 2020 Indonesia had experienced a deficit due to a decline in export performance. Of course, it is the government's duty to make policies and take appropriate steps to keep the country's economy stable. To support this, accurate information is needed to support decision making. One of them is through forecasting. The Fuzzy Time Series method was chosen as a forecasting method because of its ability to predict any real time data with arbitrary data patterns. Furthermore, to minimize error values and improve forecasting accuracy, data transformation will be carried out with Cox Boxes with the aim that the data is stationary in the variance.

In this study, it will predict the value of exports and imports of the oil and gas and non-oil and gas sectors for the next period, namely 2021 by using the Fuzzy Time Series . Then to find out more accurate forecasting results between forecasting using original data and stationary data transformed, a comparison of MAPE and RMSE values will be carried out. The expected benefits of this research include adding learning materials about the use of the Fuzzy Time Series method , as a reference or reference for other research with similar topics, and is expected to be able to provide information to the government regarding future imports and exports as a consideration in taking strategic steps.

Export is the activity of removing goods from state customs while import is the activity of entering goods into state customs. There are 2 main sectors in export and import activities, namely oil and gas (oil and gas) and non-oil and gas. Commodities included in the oil and gas sector are petroleum, LNG (Liquid Natural Gas), LPG (Liquid Petroleum Gas) and other oil products. Meanwhile, commodities in the non-oil and gas sector are divided into 3 groups, namely manufactured goods, agriculture, and mining [1]. Forecasting is defined as predicting or making predictions about the future by looking at and considering existing information. There are 2 types of forecasting methods, namely qualitative and quantitative forecasting. Quantitative methods are used when historical data (usually time series data) are available [2].

Time series data or time series is data consisting of an object consisting of time periods such as daily, monthly, yearly, and so on [3]. Time series data is said to be stationary if it does not experience drastic changes in the form of growth or decline in the data between observations. Non-stationary can be viewed from 3 aspects, namely non-stationary in average, non-stationary in variance, and non-stationary in both. Non-stationary data in the mean can be overcome by differencing, and non-stationary data in variance can be overcome by

transformation [4]. Stationarity test can be done by several methods including correlogram, unit root test, and control chart [5].

Box Cox transformation is a power transformation on the dependent variable where the variable is positive. Box Cox transformation is a power transformation on the dependent variable where the variable is positive [6,7].

$$z_t^{(\lambda)} = \begin{cases} \left(z_t^{(\lambda)} - 1\right)\lambda^{-1}, & \lambda \neq 0 \\ \ln z_t, & \lambda = 0 \end{cases}; \quad (1)$$

The value of itself is not yet known, so it is necessary to estimate by finding the value of that maximizes the following statement:

$$l(\lambda) = -\frac{n}{2}\ln\left[\frac{1}{n}\sum_{i=1}^{n}\left(z_i^{(\lambda)} - \overline{z_i^{(\lambda)}}\right)^2\right] + (\lambda+1)\sum_{i=1}^{n}\ln z_i; \quad (2)$$

Fuzzy Time Series (FTS) is a forecasting method in which it works using the principles of *fuzzy sets* . A *fuzzy* set is defined as a class of numbers with vague boundaries. Suppose $U$is a universal set, with $U = \{u_1, u_2, ..., u_n\}$.A *fuzzy set* A_i than U is defined as:

$$\begin{aligned} A_1 &= \frac{1}{u_1} + \frac{0{,}5}{u_2} + \frac{0}{u_3} + ... + \frac{0}{u_n} \\ A_2 &= \frac{0{,}5}{u_1} + \frac{1}{u_2} + \frac{0{,}5}{u_3} + ... + \frac{0}{u_n} \\ &\vdots \\ A_m &= \frac{0}{u_1} + ... + \frac{0{,}5}{u_{m-1}} + \frac{1}{u_m}; \end{aligned} \quad (3)$$

Forecasting algorithm with *Fuzzy Time Series* Chen method with Box Cox transformation is carried out with the following steps:

1. Estimation of value and data transformation
2. Transfer data by transfer model:

$$d_t = \Delta z_t^{(\lambda)} z_t^{-(\lambda)} \quad (4)$$

3. Determine the universal set (*U*) with

$$U = [D_{min} - D_1, D_{max} + D_2] \quad (5)$$

4. Determine the number of intervals and the length of the interval
5. Determine the fuzzy set (A_i)
6. Fuzzification
7. Forming FLR and FLRG
8. Defuzzification of forecasting *output* . In FTS there are 3 cases that may occur:
   Case 1)
   fuzzy logic relationship . If $A_i \rightarrow A_j$, then the forecast $F(t+1)$*output* is the median value of A_j.
   Case 2)

fuzzy logic relationships . If $A_i \rightarrow A_i, A_j, ..., A_k$, then the forecasting $F(t+1)_{output}$ is the sum of the mean values $A_i \rightarrow A_i, A_j, ..., A_k$divided by the number of *fuzzy relationships* formed.

Case 3)

fuzzy logic relationship. If $A_i \rightarrow \emptyset$,then the forecast output $F(t+1)$is the middle value of A_i.

9. Get the time variance effect value with the formula:

$$\gamma_{t+1} = \frac{1}{1 - d_{t+1}}; \quad (5)$$

10. Calculate the forecast value.

$$\hat{z}_{t+1} = \gamma_{t+1}\left(z_t^{(\lambda)}\right); \quad (6)$$

11. Transform back the final value to the original shape.

$$\hat{z}_{t+1} = \begin{cases} \left(\lambda \hat{z}_{t+1}^{(\lambda)} + 1\right)^{\frac{1}{\lambda}}, & \lambda \neq 0 \\ \exp\left(\hat{z}_{t+1}^{(\lambda)}\right), & \lambda = 0 \end{cases}; \quad (7)$$

Measurement of the error value or error rate needs to be done to find out how good a method is in making forecasts. The calculation of the error value is calculated using *Mean Absolute Percentage Error* (MAPE) and *Root Mean Squared Error* (RMSE) [8,9].

$$MAPE = \frac{1}{n}\frac{\sum|y - \bar{y}|}{y}100\%; \quad (8)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\hat{y} - y)^2}; \quad (9)$$

The smaller the MAPE value, the better the forecasting performance results. MAPE value categories can be seen in the following Table 1.

Table 1. MAPE Nilai Value Criteria

Score	Information
< 10%	The forecast results are very good
10% - 20%	Good prediction result
20% - 50%	Prediction results are sufficient
>50%	Bad forecast result

2. METHODS

In this study, historical data on exports and imports of Indonesia's oil and gas and non-oil and gas sectors were used obtained from the Central Statistics Agency. The data is in the form of a monthly time series from 2011 – 2020 with different data patterns. The data processing stage consists of several steps, namely estimating the value of for the transformation, data transformation with Box Cox transformation, forecasting stage with *Fuzzy Time Series*, and calculating the *error value* with MAPE and RMSE.

3. RESULTS AND DISCUSSION

3.1 Descriptive Statistical Analysis

Statistical analysis was conducted with the aim of providing an overview of the characteristics of the research variables. Statistical analysis of variables was carried out by looking at the average value, standard deviation, and looking at it as a whole through the time series plot (*time series* data). The following is a comparison of the value of exports and imports of the oil and gas sector and non-oil and gas sector over the last 10 years.

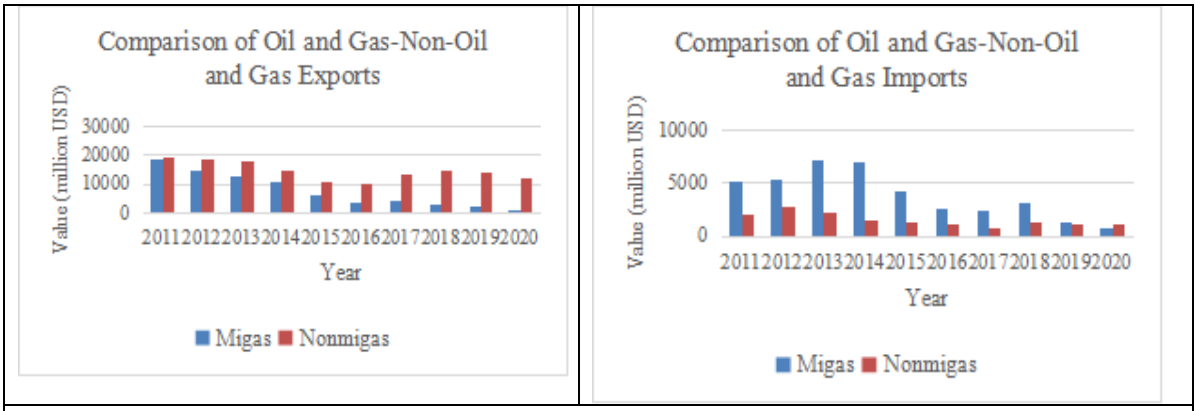

Figure 1. Comparison of Oil and Gas Non Oil and Gas Exports (left), Comparison of Oil and Gas-Non-Oil and Gas Imports (right)

With a description of the data presented in the following Table 2:

Table 2. Description of Indonesia's Import Export Data

Data	*mean*	Standard Deviation	D_{min}	D_{max}
Oil and Gas Export	656.80	506.07	37.32	2382.20
Non-Export	1219.19	290.89	721.98	1927.31
Oil and Gas Import	327.22	199.11	9.12	869.08
Import Non	130.45	62.37	46.93	350.86

Based on the picture above, it can be seen that the value of exports and imports in the oil and gas sector has fluctuated in value which tends to decrease from year to year with the lowest achievement value being in 2019 - 2020. While in the non-oil and gas sector, the value of

exports and imports in 2011 - 2016 has decreased. periodically then the value increases in 2017 – 2018 and falls again in the following year.

3.2 Cox's Box Transformation

Before performing the transformation, first estimate the value λthat will be used. In [10] The first step is to determine the set of values $\lambda$to be estimated. Suppose specified λ $\{0, 0.1, 0.2, 0.3, 0.4\}$. Next, substitute each value λinto Equation (3) to find the $l(\lambda)$ maximum value. The estimation results are presented in the following table:

Table 3. Estimated Valueλ

λ	$l(\lambda)$
0	747.36
0.1	1025,48
0.2	943.07
0.3	894.20
0.4	858.55

seen from the table above that the value $\lambda = 0{,}1$produces the $l(\lambda)$maximum value of 1025.48. So that $\lambda = 0{,}1$ is chosen to be the value λthat will be used in the transformation. To get the transformation data , it is $\left(z_t^{(\lambda)}\right)$ done by substituting the export-import data into Equation (2), then substituting the transformation data into Equation (4) to get the data transfer value (d_t) as in the example of the transformation for oil and gas export data in the following table of results:

Table 4. Transformation Results

Period	$z_t^{(\lambda)}$	d_s
Jan-11	10.1236	-
Feb-11	9.9418	-0.0183
⋮	⋮	⋮
Nov-20	5.5951	0.1071
Dec-20	5.5715	-0.0042

3.3 Fuzzy Time Series Forecasting

1. Forming the Universal Set (U).

   The minimum and maximum values of $d_t$each oil and gas export are obtained $D_{min} = -0{,}3544, D_{max} = 0{,}1821$. Then also determine any value, for example $D_1 = 0{,}001$and $D_2 = 0{,}002$. Then a universal set for oil and gas export data can be formed, namely:

   $U = [-0.3545, 0.1822]$.

2. Specifies the Length and Number of Intervals. Determine the length of the interval $(l)$and the length of the interval $(\mathrm{p})$with

$$l = \frac{2(IQR)}{\sqrt[3]{n}} = 0{,}0237$$

$$p = \frac{[(D_{max} + D_2) - (D_{min} - D_1)]}{l} \approx 23$$

3. Then divide the universal set into 23 intervals with the fuzzy set:

$$A_1 = \frac{1}{u_1} + \frac{0.5}{u_2} + \frac{0}{u_3} + \ldots + \frac{0}{u_{22}} + \frac{0}{u_{23}}$$

$$A_2 = \frac{0.5}{u_1} + \frac{1}{u_2} + \frac{0.5}{u_3} + \ldots + \frac{0}{u_{22}} + \frac{0}{u_{23}}$$

$$\vdots$$

$$A_{22} = \frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \ldots + \frac{1}{u_{22}} + \frac{0.5}{u_{23}}$$

$$A_{23} = \frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \ldots + \frac{0.5}{u_{22}} + \frac{1}{u_{23}}$$

4. The next step is fuzzification by classifying each data into a *fuzzy set* according to the interval range that contains the data.

Table 5. Fuzzification

Period	Score	Fuzzification
Feb-11	-0.0183	A_{15}
Mar-11	0.0433	A_{17}
⋮	⋮	⋮
Nov-20	0.1071	A_{20}
Dec-20	-0.0042	A_{15}

5. Then form FLR and FLRG based on *current state* and *next state* data. For example, fuzzification of time series data $F(t-1)$as *current state* is $A_i$and fuzzification in $F(t)$the *next state* is A_j.Then the *fuzzy logic relationship* in that state can be written as$A_i \rightarrow A_j$.

Table 6. *Fuzzy Logic Relations*

Period	FLR
Mar-11	$A_{15} \rightarrow A_{17}$
Apr-11	$A_{17} \rightarrow A_{18}$
⋮	⋮

Nov-20	$A_{15} \rightarrow A_{20}$
Dec-20	$A_{20} \rightarrow A_{15}$

6. Furthermore, the FLR that has been formed will be grouped into groups based on the same LHS (*left hand side*) or *current state* .

Table 7. *Fuzzy Logic Relations Group*

Group	FLRG
1	$A_1 \rightarrow A_{23}$
2	$A_2 \rightarrow \emptyset$
⋮	⋮
22	$A_{22} \rightarrow \emptyset$
23	$A_{23} \rightarrow A_{13}$

7. *fuzzy* logic relation group is formed, then perform value defuzzification using 3 defuzzification cases. The defuzzification results are shown in the following table:

Table 8. Defuzzification

Group	Defuzzification
1	0.17962
2	-0.31889
⋮	⋮
22	0.155881
23	-0.05777

8. Get the time variance value $(\gamma_t)$by substituting the defuzzification value into Equation (5). The example for March 2011 data has a defuzzification value of 0.007515, then the time variance value for group 15 (γ_{15})is

$$\gamma_{15} = \frac{1}{1 - defuzzi_{15}} = \frac{1}{1 - 0{,}007515} = 1{,}007572$$

9. Then the value for forecasting is calculated by Equation (6). The forecast for March 2011 data is

$$\bar{z}^{(\lambda)}_{Mar11} = \gamma_{15} z^{\lambda}_{Feb11} = 1.007572(9.9418) = 10.0274$$

10. Perform the reverse transformation with Equation (7) to convert to the original value which has units. The final value for the results of the March 2011 data forecast is

$$\bar{z}_{Mar11} = \left(\lambda z^{\lambda}_{Mar11} + 1\right)^{1/\lambda} = 1038.116 \text{ (juta USD)}$$

Forecasting results for oil and gas export data are presented in the following Table 9.

Table 9. Forecasting Oil and Gas Export Data

Period	Value (million USD)	
	Actual	Forecasting
Mar-11	1243.15	1038.116
Apr-11	1818.87	1139,777
⋮	⋮	⋮
Nov-20	85.09	59.17034
Dec-20	83.81	82.3128
Jan-21	-	86,42733

And the forecasting results for the next 12 months are as follows Figure 2 and Figure 3.

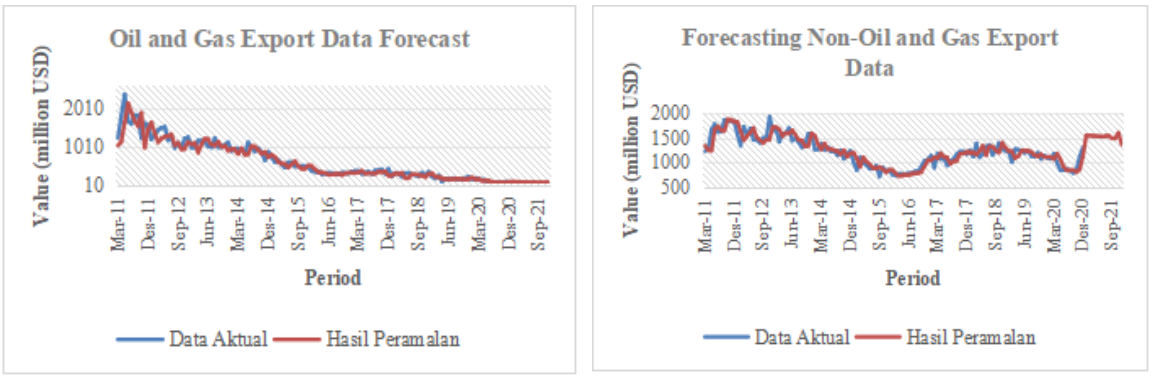

Figure 2. Forecast comparison of oil and gas data exports (left), forecast comparison of Non-oil and and gas exports (right)

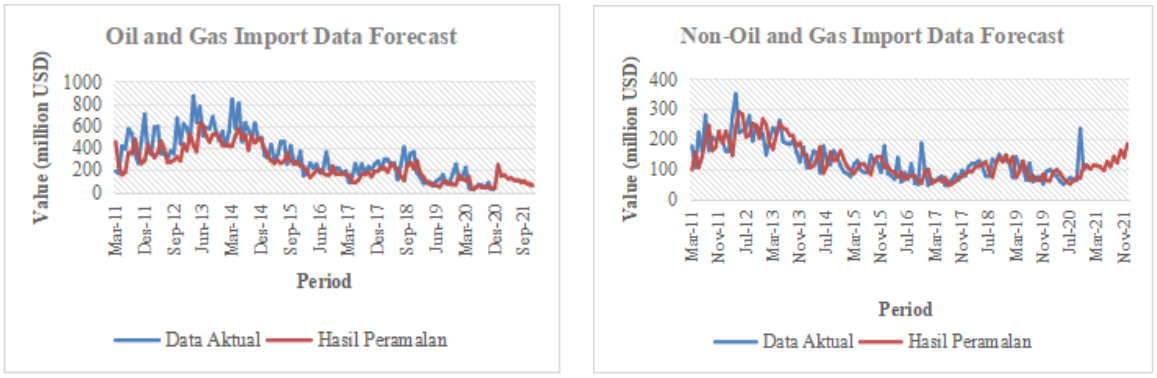

Figure 3. Forecast comparison of Oil and Gas Imports (left), forecast comparison of Non-Oil and Gas Imports (right)

Based on the graphic image of the forecasting results, it is known that the forecast value is not much different and still follows the pattern of the actual data. From the graph, it can also be seen that the forecast for the value of import exports for 2021. The forecasting results predict that in 2021, the value of exports and imports in the oil and gas sector will fluctuate but tend to decline until the end of the year to reach around 50 million USD. In contrast to the estimated value of

exports and imports in the non-oil and gas sector, which also fluctuated and experienced an increase from the previous year.

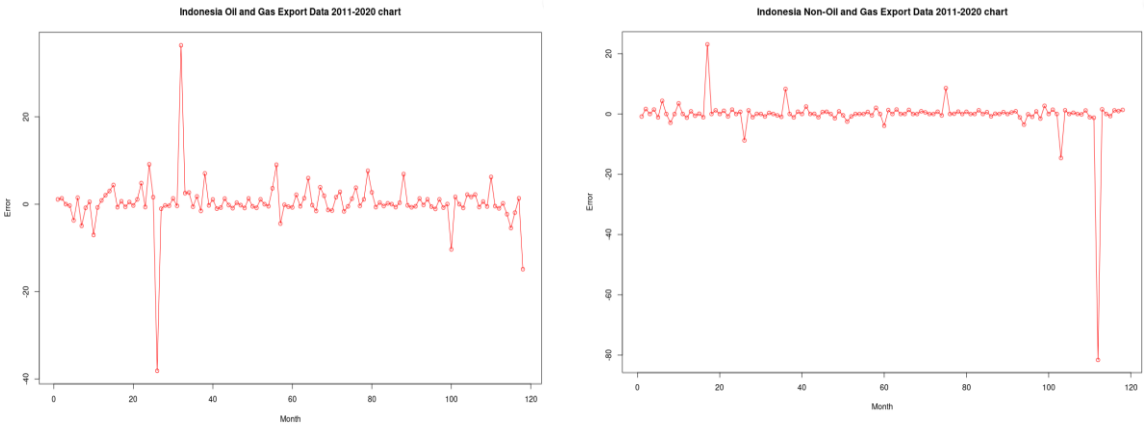

Figure 4. Error Forecast comparison of Oil and Gas Exports (left), forecast comparison of Non-Oil and Gas Exports (right)

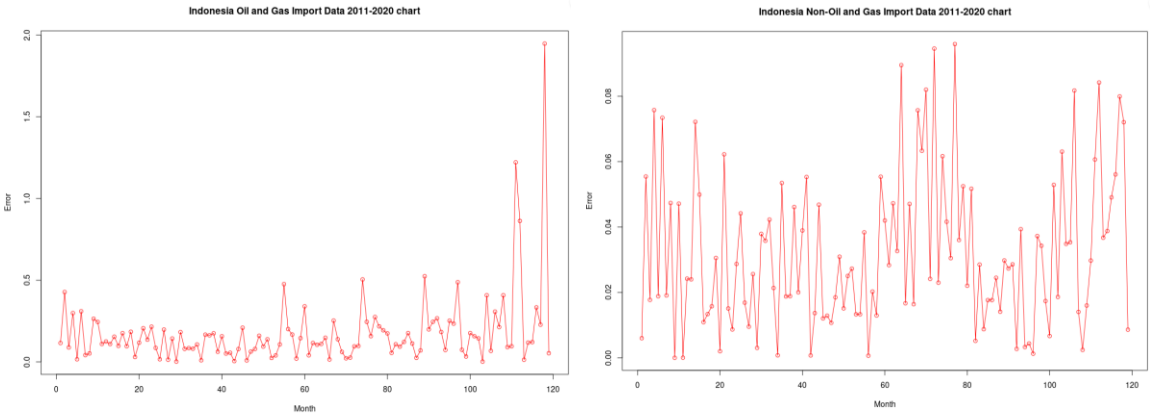

Figure 5. Error Forecast comparison of Oil and Gas Imports (left), forecast comparison of Non-Oil and Gas Imports (right)

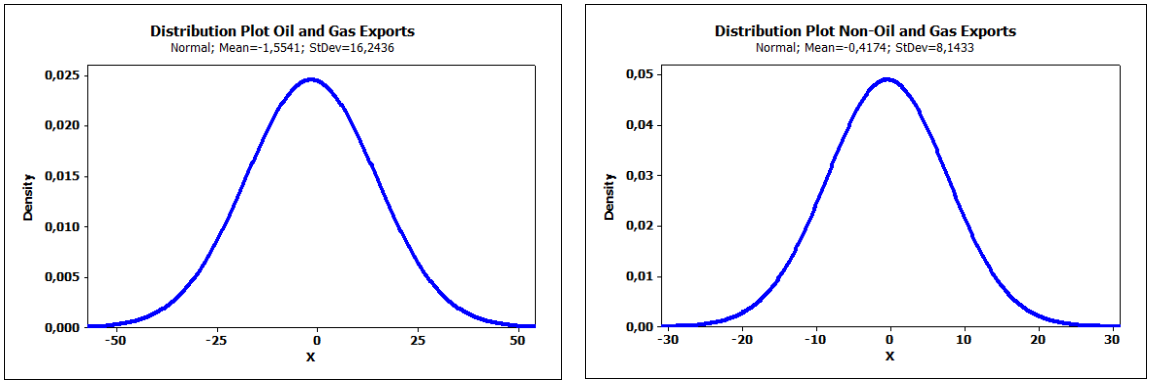

Figure 6. Mean and St.Dev Oil and Gas Exports (left), Mean and St.Dev Non-Oil and Gas Exports (right)

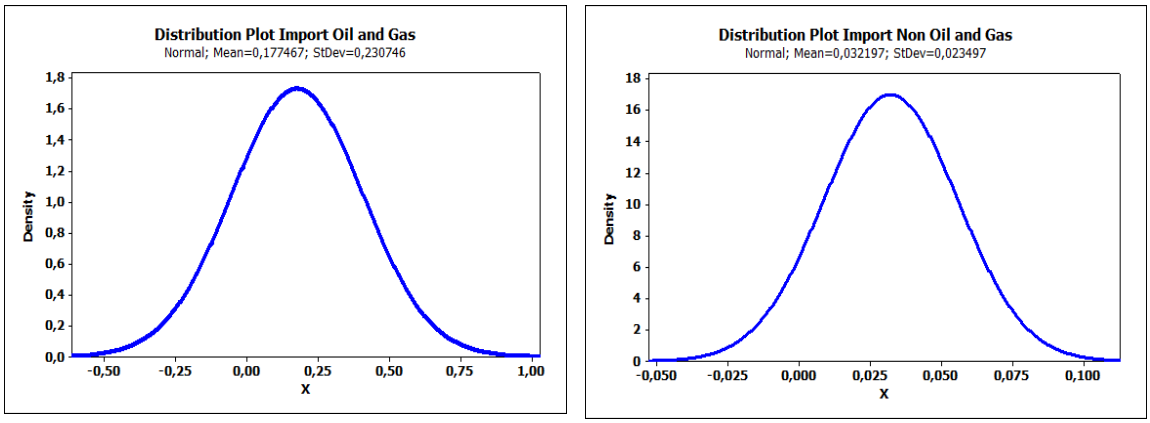

Figure 6. Mean and St.Dev Oil and Gas Imports (left), Mean and St.Dev Non-Oil and Gas Imports (right)

Furthermore, MAPE and RMSE calculations are carried out to determine the *error value* and the level of forecasting accuracy. The comparison of the error values for forecasting with the original data and the transformation is presented in the following Table10 and Table 11.

Table 10. Comparison of MAPE

Data	MAPE	
	Original	Transformation
Oil and Gas Export	58.42%	16.48%
Non-Oil and Gas Exports	11.26%	8.24%
Oil and Gas Import	66.83%	30.17%
Non-Oil and Gas Import	54.37%	23.34%
Average	78.89%	19.56%

Table 11. Comparison of RMSE

Data	RMSE	
	Original	Transformation
Oil and Gas Export	188.64	175.23
Non-Oil and Gas Exports	151.56	131.38
Oil and Gas Import	130.62	134.06
Non-Oil and Gas Import	57.56	45.43
Average	132.09	121.52

Based on the comparison of MAPE and RMSE values in the table above, it is found that forecasting using the transformation data that has been stationary on the variance is more accurate because it has an average MAPE value of 19.56% and RMSE 121.52. With MAPE values below 20%, forecasting using stationary data can be said to be better than using non-stationary data.

4. CONCLUSIONS

After calculating and analyzing the discussion, the following conclusions can be drawn: The application of the Box Cox transformation to the times series data produces forecasts with a good level of accuracy. From the results obtained, the error value in forecasting with transformation data is smaller, namely MAPE 19.56% and RMSE 121.52. Meanwhile, forecasting with original data has a MAPE value of 74.89% and RMSE 132.09. The value of exports and imports in 2021 is expected to continue to fluctuate. In the oil and gas sector, the value of exports and imports decreased from the previous year to reach USD 50 million. Meanwhile, in the non-oil and gas sector, the value of exports and imports increased from the previous year.

Some suggestions for this research and further research are the Indonesian government should make more efforts to encourage export activities in the following years, especially in the oil and gas sector which tends to continue to decline. Suggestions that researchers can give to further researchers in developing the FTS method are to use other FTS algorithms and other more effective interval length determination methods. Another suggestion for future researchers is to use other data transformation methods in overcoming the problem of stationary data variety to produce a good level of accuracy.

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