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E-ISSN:2614-1280 P-ISSN 2622-4771
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INDONESIAN CONSUMER PRICE INDEX (CPI) FORECASTING USING AN EXPONENNTIAL SMOOTHING-STATE SPACE MODEL

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Abstract: *CPI (consumer price index) is one of the economic measurement tools that can explain or inform about the development of prices for services/goods consumed or used by consumers. The CPI is related to determining inflation, therefore the CPI and inflation are important variables in viewing the economic conditions of a particular country or city. Current month inflation depend on previous CPI and current CPI. The CPI and inflation are so important that many researchers are studying inflation and the CPI. The purpose of this research is to predict the value of Indonesia's monthly CPI with a simple, easy, and highly accurate forecasting model using open-source software. The data used are monthly CPI data from the Central Statistics Agency (BPS) for January 2014 to August 2024. The benchmark for the best ETS model is based on the minimum value of the Akaike information criteria (AIC) and Bayesian information criteria (BIC). The best model obtained is the ETS (M, N, N) model with a smoothing parameter (α) of 0.9933, has a root mean square error (RMSE) of 3.275868 and a mean absolute percentile error (MAPE) of 0.6595211%.*

Keywords: *Price Consumer Index (PCI), Forecasting of Indonesia PCI,* ***,*** *Exponential Smoothing-State Space, ETS (M,N,N).*

1. Introduction

The consumer price index (CPI) is part of the important economic indicators that can provide information regarding the development of the price for goods/services paid by consumers" (BPS, 2024). CPI is related to deciding to swell, whereas swelling is characterized as an increment within the cost of merchandise and administrations in common, where these merchandise and administrations are necessities for the community or can too be said to be a diminish within the offering control of a country's money (BPS, 2024). Inflation can be measured using the consumer price index (CPI) method. Inflation and CPI are important variables in seeing problems or economic developments in a particular country or city (Robbayani, Riaman, & Subbarini, 2022). One of the factors that determine inflation is the CPI. Current month inflation depend on previous CPI and current CPI (Utari, Kristina S, & Pambudi, 2016).

Between CPI and inflation must be stable so that the country's economy can be stable, inflation is so important that the Indonesian government formed a national inflation control team (TPIN) based on Presidential Decree Number 23 of 2017. This TPIN was also formed at the provincial and city/district levels (Keppres_23, 2017). To control inflation and CPI, we often hear about

International Journal of Economics, Business and Accounting Research(IJEBAR)
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necessities or staple food market operations in city/district markets that aim to control inflation and CPI. CPI and inflation are so important, that many researchers have studied the CPI value, including a study on consumer price index prediction and inflation in Zambia. This research uses double exponential smoothing (DES) from Holt and the ARIMA model. The final of study showed that DES is worse than the ARIMA model, but for software tools, it is easier to use the DES model from Holt (Jere, 2016). Another study is on CPI in Yogyakarta. This research uses a double exponential smoothing (DES) model from Brown's. The forecasting accuracy used the mean absolute percentage error (MAPE) of 0.1308443%. DES model one-parameter from Brown's is simple and accurate in this research(Febriyanti, Pradana, Saputra, & Widodo, 2021). The Indonesian CPI study using the backpropagation artificial neural network method produced a MAPE of 0.463% with input neuron value parameters equal 6, hidden neuron value equal 10, initial weight range value in the range of -1 to 1, learning rate value equal 0.1, and epoch value equal 5000 (Madani, Furqon, & Hidayat, 2020). Research on forecasting the Indonesian CPI used ARIMA and obtained the best final result of the ARIMA (2,1,3) model with a mean square (MS) value of 0.1744 (Mukron, et al., 2021). A study on forecasting the Indonesian CPI using Seasonal Autoregressive Integrated Moving Average (SARIMA) obtained the best final result of the SARIMA (0,1,1)(0,1,1)12 model with a MAPE value of 0.26% (Yahya, 2022). Research using simple and accurate good forecasting models includes a study on inflation forecasting in Indonesia using the moving average method, SES, and DES. The final result in the conclusion that the best method is SES with an alpha value of 1.316, MAPE of 7.76202, mean absolute deviation (MAD) of 0.27343, and mean square deviation (MSD) of 0.14625 (Sudibyo, Iswardani, Septyanto, & Wicaksono, 2020).
From much last research, CPI prediction is important in addition to the inflation that occurs which is interrelated. This study aims to forecast the CPI value with a simple, easy, and highly accurate prediction model. The ES model has the convenience of not having statistical assumptions and using software that is easily available and free to download. The development of the ES model is a model development by looking at the state-space known as the exponential smoothing-state space model or some call it the ETS model (decomposition of error, trend, and seasonality). The ETS model is a decomposition model of the ES model so that it can explore data deeper and raise forecasting accuracy (Hyndman & Athanasopoulos, 2021).

2. Research Method

This research uses secondary data from the monthly consumer price index (CPI), starting from January 2014 to August 2024 equal to 128 data obtained from the website of the Central Statistics Agency (BPS) Jakarta. To calculate the CPI based on the price of types of goods and consumption value is (modified Laspeyres) (BPS, 2024):

$$IHK_n = \frac{\sum_{i=1}^{k} \frac{P_{ni}}{P_{(n-1)}} P_{(n-i)i}\ Q_{oi}}{\sum_{i=1}^{k} P_{oi}\ Q_{oi}} x100$$

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where,
IHKn : index of period n
P_{ni} : the price of a type for goods i, for period n
$P_{(n-1)I}$: type for price of goods I, for period n-1
$P_{(n-1)i}. Q_{Oi}$: consumption value of the type of goods i, for period n-1
$P_{oi}. Q_{Oi}$: consumption value of a type of goods i, in the base year
K : number of types of commodity of package goods

There is a relationship between CPI and inflation, where inflation is calculated using CPI. Inflation CPI can be calculated using inflation as below formula (Utari, Kristina S, & Pambudi, 2016):

$$Inflasi_t = \left(\frac{IHK_t}{IHK_{t-1}} - 1\right) x\ 100\%$$

where,
t : the inflation of month/quarter/year t
IHK_t : the *CPI* of month/quarter/year t
IHK_{t-1} : the *CPI* of month/quarter/year t-1

There are 3 exponential smoothing models, namely the SES model, the DES model, and triple exponential smoothing (TES). The three models are as follows (Hyndman & Athanasopoulos, 2021). The SES model is suitable for stationary data with data fluctuations. Here is the SES model:

$$F_t = F_{t-1} + \alpha\,(A_{t-1} - F_{t-1})$$

where:
Ft : New forecast
F_{t-1} : Previous forecast
α : Smoothing constant ($0 \leq \alpha \leq 1$)
A_{t-1} : Actual demand of the previous period

There are 2 double exponential smoothing (DES) models, namely from Brown for one parameter and from Holt's for double parameters. Both models are suitable for trending data. Here is the double exponential smoothing (DES) model from Holt's:

$$\hat{Y}_{t+p} = A_t + T_t p$$
$$A_t = \alpha Y_t + (1-\alpha)\,(A_{t-1} + T_{t-1})$$
$$A_t = \alpha Y_t + (1-\alpha)\,(A_{t-1} + T_{t-1})$$

Yt : the actual data of period t,
At : the exponential smoothing value,
α : the non-trend smoothing constant,
β : the smoothing constant for trend estimation,

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Peer Reviewed–International Journal
Vol-8, Issue-3, 2024(IJEBAR)
E-ISSN:2614-1280 P-ISSN 2622-4771
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T_t : the trend estimation,
$\hat{Y}$: the forecast value for the next period and
p : the number of periods predicted.

The triple exponential smoothing (TES) model is often referred to as the Winters model. There are 2 types of TES models, namely the additive model and the applicative model. The following is an additive TES model.

$$\hat{y}_{T+p}(T) = \ell_T + pb_T + sn_{T+p-L} \qquad (p = 1, 2, 3, \dots)$$
$$\ell_T = \alpha\,(y_T - sn_{T-L}) + (1-\alpha)\,(\ell_{T-1} + b_{T-1})$$
$$b_T = \gamma\,(\ell_T - \ell_{T-1}) + (1-\gamma)\,b_{T-1}$$
$$sn_T = \delta\,(y_T - \ell_T) + (1-\delta)\,sn_{T-L}$$

where,
ℓ_T : exponential smoothing estimate
b_T : trend estimate
sn_T : seasonal estimate

where α is the smoothing coefficient,
γ is the trend coefficient, and
δ is the seasonal coefficient
the values of α, γ and δ are between 0 and 1
L is the seasonal length.

To show the trend pattern in the data, a data stationarity test can be carried out using the "Dicky Fuller test". The "Dicky Fuller test" has Ho and H1 as follows (Farida & As'ad, 2021):

Ho: ϕ = zero (data is not stationary)
H1: $\phi \neq$ zero (data is stationary)
The test of statistics are as follows:

$$ADF_t = \frac{\widehat{\emptyset} - 1}{SE(\emptyset)}$$

Test decision: If the ADFt test value < from the critical point value of the t-student distribution then accept Ho or the p-value (ADFt test probability value) > from alpha (5%, significance level) then accept Ho.

The ETS model is a model that is the result of the development of the exponential smoothing (ES) model through a state space approach also called the ETS model. The ETS model can be built from the SES model, one-parameter and two-parameter DES, and the TES or Winter model for additive and multiplicative models. According to Hyndman & Athanasopoulos, there are 30 models for

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ETS. In this study, one of the most suitable ETS models was chosen for use in forecasting the Indonesian CPI. ETS itself stands for error (E), trend (T), and (S) for seasonal. An example, the ETS(M, N, N) model has a multiplicative error (M), has a none trend (N) or does not have a trend, and has no seasonal (N) or does not have seasonality. The ETS(M, N, N) model can be said in other words as a Simple Exponential Smoothing (SES) model that has multiplicative errors. The ETS(M, N, N) model has the following equation (Hyndman & Athanasopoulos, 2021):

$$y_t = l_{t-1}\,(1 + \varepsilon_t)$$
$$l_t = l_{t-1}\,(1 + \alpha\varepsilon_t)$$

where :
y_t : the actual data of period t,
l_{t-1} : $y_{\mathbf{t}}|_{t-1}$

As a determinant to determine the best model, the Akaike Information Criteria(AIC) and Bayesian Information Criteria(BIC) values will be used. The AIC value can be calculated using the formula:

$$AIC = -2\left(\frac{L\,L}{T}\right) + \left(\frac{2tp}{T}\right)$$

where,
LL : *loq-likelihood*
tp : total parameters
T : the number of data

BIC value formulated as follow:

$$BIC = -2\,L\,L + k\ln(T)$$

where,
LL : *loq-likelihood*
k : estimation of the parameter model
T : the amount of data

The model is the best if the *AIC* value and *BIC* values are the minimum (Jofipasi, Miftahuddin, & Hizir, 2017).

This research uses the R package statistics, by activating the smooth library with ETS command. When run, the program will display the best ETS model on the minimum AIC value and BIC values. The minimum AIC value and BIC values are used to determine the best model in the same model class, while to determine the accuracy of the forecasting results, the Root Mean Square Error(RMSE) value and Mean Absolute Percentage Error(MAPE) values are used. The RMSE value and MAPE values can be calculated with the following formula(As'ad, Sujito, & Setyowibowo, 2020):

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$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} e_i^2}{n}}$$

The *MAPE* value formulated as follow :

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{e_i}{y_i}\right|$$

where,
e_i : the i error
y_i : the i data
n : the number of data

To find out whether the forecasting results are very good, good, sufficient, or bad, it can be seen with the MAPE value, which is the average percentage error value of the actual data. The following is Table 1. forecasting result criteria (Hajjah & Marlim, 2021):

Table 1. The Criteria *of MAPE* Value

Value of MAPE (X)	Description
X < 10 %	Very Good
10 % ≤ X < 20 %	Good
20 % ≤ X < 50 %	Sufficient
X ≥ 50 %	Bad

In Table 1, it can be seen on the basis of the MAPE value, whether the results of forecasting are very good, good, sufficient, or bad.

The steps in conducting ETS modeling are as follows:
1. Reading data with the R package and plotting the data.
2. Modeling with the ETS model and calculating AIC and BIC.
3. Choosing an ETS model with minimum AIC and BIC values.
4. Calculating RMSE and MAPE values.
5. Determining the forecasting result criteria using MAPE.
6. Using the ETS model to predict for the next period.

3. Results And Discussion

3.1. Results

This research uses secondary data on the Indonesian monthly CPI from January 2014 to August 2024. The data was sourced from the Central Bureau of Statistics (BPS). The first step in this research is to prepare the data and plot the data which can be presented in Figure 1 below:

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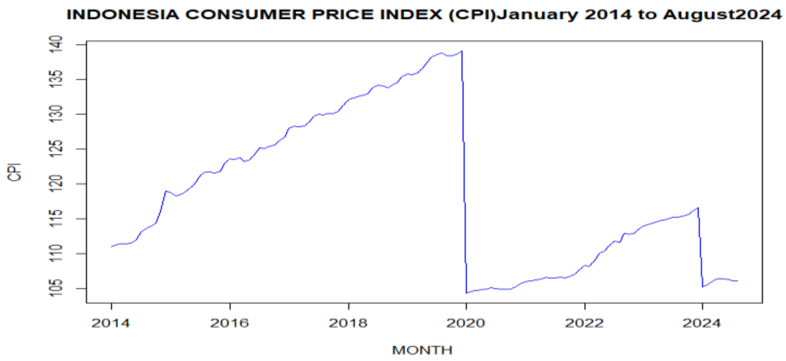

Figure 1. The graphic of monthly CPI of Indonesia (January 2014 – Agustus 2024, *BPS*)

From Figure 1, there was a continuous increase in CPI from early January 2014 to 2020, it decreased drastically, this may be inflation, and CPI that occurred was controlled by TPIN which was formed in 2017. After 2020 it rose again and decreased in 2024. The first step has been done by preparing data and plotting the data in Figure 1.

Next, an analysis was carried out with the ETS model, namely conducting a stationarity test (Dicky Fuller test) of the data to determine the presence of a trend pattern, and the results are presented as follows:

Tabel 2. Results Test of the Dickey--Fuller

Augmented Test for Dickey--Fuller
Data : ihk Dickey--Fuller : -2.2733, Lag order : 5, p--value : 0.4629 alternative hypothesis : stationary

In table 2, the DFT-test value is -2.2733, p-value is 0.4629. If the p-value (0.4629) is greater than 0.05 then Ho is accepted which means the data is not stationary. The ETS model might be suitable for this is T or trend containing A (A: additive) or M (M: multiplicative) because it is not stationary / there is a trend. Possible ETS models are ETS(N, A, N), ETS(N, M, N), ETS(A, A, N), ETS(M, A, N), ETS(M, M, N) and one more ETS(M, N, N) recommended by the R package. The first selection is by looking at the minimum AIC value and BIC values because they are still in the same ETS model class. Here are the results in Table 3:

Table 3. Results of *AIC* and *BIC* values for several ETS models

Model	*AIC*	*BIC*	Description
(N, A, N)	-	-	Invalid error type
(N, M, N),	-	-	Invalid error type
(A, A, N)	934.8227	949.0828	
(M, A, N)	899.7787	914.0388	
(M, M, N)	899.8053	914.0655	
(M, N, N) from ***R*** package	895.7580	904.3141	The smallest *AIC* and *BIC* values

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From Table 3 it appears that the ETS model that has the minimum AIC value and BIC values is the ETS (M, N, N) model, namely: 895.7580 (AIC) and 904.3441 (BIC). Furthermore, the selected ETS(M, N, N) model is used for forecasting in this study. The complete results of the ETS (M, N, N) model are presented in the following table 4:

Table 4. Results of the Model for *ETS (M, N, N)*

ETS(M,N,N)							
Parameter of smoothing : alpha : 0.9933							
Initial states : l : 110.9299 sigma : 0.0243							
AIC 895.7580	AICc 895.9515	BIC 904.3141					
Training set error measures :							
	ME	RMSE	MAE	MPE	MAPE	MASE	ACF1
Training set	-0.03829907	3.275868	0.7381049	-0.07645856	0.6595211	0.09765854	-0.005346714

From Table 4, the ETS(M, N, N) model has a smoothing parameter (α) of 0.9933, a forecasting accuracy value for RMSE of 3.275868, and an accuracy value for MAPE of 0.6595211%. The MASE value of 0.659511% is less than 10%, which means the forecasting is very good.

After obtaining the best forecasting model, it is used to forecast the next 4 months, namely September, October, November, and December. The forecasting results with a significance level of 5% (alpha: α) are presented in the following table 5:

Table 5. Forecast Results for the Next 4 Months of the ETS (M,N,N) Model

Month	September	October	November	December
Lower Forecast Limit	101.0026	98.93033	97.33637	95.99093
Forecast Value	106.0602	106.0602	106.0602	106.0602
Upper Forecast Limit	111.1178	113.1901	114.7840	116.1295

From table 5, it shows that the flat forecast value is 106.0602 from September to December with the lower limits and upper limits of the forecast widening. Its model is almost similar to the Single Exponential Smoothing (SES) model which has a flat forecast value, which means the ETS(M, N, N) model can be used for short-term forecasting (one or two periods ahead). The following shows the ETS forecast value (M, N, N) and the original CPI data from January 2014 to August 2024:

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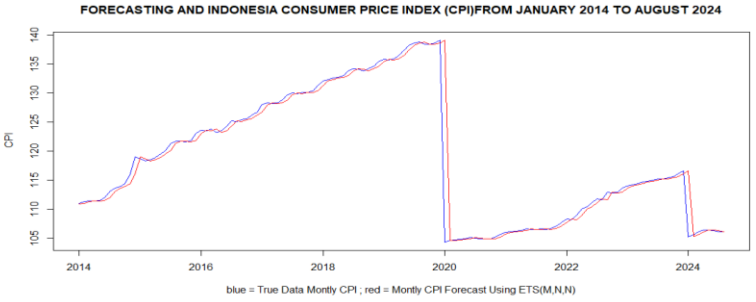

Figure 2. The graphic of monthly *CPI* of Indonesia and forecasting (January 2014 – Agustus 2024, *BPS*)

From Figure 2, it shows that the monthly CPI data coincides with the forecast value. From 2014 to 2019, there was a drastic uptrend and a downtrend in 2020. Then it continued to rise again until it fell again in 2024, this was followed by the forecast value which seemed to overlap.

3.2. Discussion

The model of ETS (M, N, N) is a model with multiplicative errors without trends and seasonality, this is similar to the SES model. It is a model for forecasting data without trends and seasonality. The model of ETS(M, N, N) can be used to make short-term forecasts (1 or 2 periods ahead) because the forecast results will be the same. The addition of the latest data each period can update the model so that it can get very good forecast results. Previous research by Yahya (2020) examined the prediction of the Indonesian CPI using the SARIMA (0,1,1) (0,1,1)12 model, obtaining a MAPE result of 0.26% (very good), while this study obtained a MAPE of 0.6595211% (very good). The SARIMA model is more difficult than the ETS model which gets equally very good forecast results with CPI data for different periods. This study starts from 2014 to 2024 with a graph showing a drastic decline in data twice, namely in 2020 and 2024, while the data used by Yahya (2020) from the graph shows a trend and may be seasonal. The seasonality can be seen from the SARIMA model with a seasonal length of 12 months. It should be noted that the period from 2014 to 2024 occurred 2 times (2020 and 2024) a drastic decline in the CPI index, is this because of the existence of a national inflation control team (TPIN) that controls inflation and has an effect on the decline in the CPI index, this certainly requires separate research.

4. Conclusion

From the results of this research, it is the best ETS model for forecasting the Indonesian monthly consumer price index (CPI). The ETS(M, N, N) model has a smoothing parameter (α) of 0.9933, a forecasting accuracy value for RMSE of 3.275868, and an accuracy value for MAPE of 0.6595211% (very good). The model of ETS(M, N, N) means a model with a single exponential smoothing multiplicative error with a multiplicative error. The model of ETS(M, N, N) is suitable for short-term forecasting (1 or 2 periods ahead). To get forecasting results that still have high accuracy, it is expected to update the model by adding the latest data in the model update.

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International Journal of Economics, Business and Accounting Research(IJEBAR)
Peer Reviewed–International Journal
Vol-8, Issue-3, 2024(IJEBAR)
E-ISSN:2614-1280 P-ISSN 2622-4771
https://jurnal.stie-aas.ac.id/index.php/IJEBAR

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