Forecasting Infant Mortality Rate for China: A Comparison Between α-Sutte Indicator, ARIMA, and Holt-Winters

Nuning Kurniasih¹, Ansari Saleh Ahmar²*, Dadang Rahmat Hidayat¹, Herlina Agustin¹, & Edwin Rizal¹

¹Faculty of Communication Sciences, Universitas Padjadjaran, Bandung, Jawa Barat 45363, Indonesia
²Department of Statistics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Makassar, Makassar, Indonesia

*ansarisaleh@unm.ac.id

Abstract. The purpose of this study is to apply the α-Sutte Indicator in forecasting data. α-Sutte Indicator is a new forecasting method that was developed in 2017 by Ansari Saleh Ahmar. To see the accuracy of these methods, the forecasting results of the α-Sutte Indicator will be forecasting methods compared to other items, namely: ARIMA and HoltWinters. Based on the results of forecasting, it is found that α-Sutte Indicator has MSE and MAPE values that are lower than other methods (ARIMA and HoltWinters). This is supported by MSE data from α-Sutte Indicator smaller than ARIMA(2,2,2) and HoltWinters i.e. 0.03; 3.06; and 3.15.

1. Introduction
Forecasting is an important data, because of the existence of data forecasting that can help in determining decisions to take forward. Forecasting will provide information about anything that will happen in the future. The old data will be used as reference data in predicting the future data. There are several types of forecasting which are often used such as α-Sutte Indicator [1], ARIMA [2], Holt Winters [3], Neural Network Time Series, Robust Exponential Smoothing, and Theta Model. Each of these forecasting methods has its own advantages and disadvantages. Therefore, to obtain a good forecasting, a method must have a high level of accuracy with the minimum error rate. To see the accuracy each of the forecasting methods it will compare the error value of each method, which method that has a minimum error rate. To measure the accuracy of a method, there are several methods that can be used, such as MSE, MAPE, and MACD. In this study, to compare the accuracy of the α-Sutte Indicator implementation in predicting data, it will be compared with other forecasting methods i.e. ARIMA and HoltWinters Method.

1.1. ARIMA and SARIMA
A process Z_{t} is stated as following a mixed-autoregressive-moving average or ARMA (p,q) model, if it meets [4][8]:

\[ \phi_p(B)Z_t = \theta_q(B)\alpha_t \]

(1)

where \( \phi_p(B) = 1 - \phi_1B - \phi_2B^2 - \ldots - \phi_pB^p \) (for AR(p))
and \( \theta_q(B) = (1 - \theta_1 B - \theta_2 B^2 - ... - \theta_q B^q) \) (for MA(q))

If there is a non-seasonal difference, so that it becomes ARIMA(p,d,q) model as follows [5]:

\[
\phi_p(B)(1-B)^d Z_t = \theta_q(B) a_t,
\]

(2)

where \( \phi_p(B) = (1 - \phi_1 B - \phi_2 B^2 - ... - \phi_p B^p) \) (for differencing non seasonal) and \( \theta_q(B) = (1 - \theta_1 B - \theta_2 B^2 - ... - \theta_q B^q) \) (for MA(q)).

Seasonal ARIMA model (SARIMA) is the same as non-seasonal ARIMA model. A process \( Z_t \) is stated as following a mixed autoregressive-moving average model that is expanded for handling seasonal aspect or ARMA (p,d)(P,D)\(^s\) if it satisfies [5]:

\[
\Phi_p(B^s) \phi_p(B)Z_t = \theta_q(B) \Theta_Q(B^s) a_t,
\]

(3)

If there is a seasonal difference on Seasonal ARIMA model, so the model becomes as follows:

\[
\Phi_p(B^s) \phi_p(B)(1-B)^d (1-B^s)^D \tilde{Z}_t = \theta_q(B) \Theta_Q(B^s) a_t
\]

1.2. Holt-Winters

There are 2 types of Holt-Winters methods applied on this research namely Multiplicative Holt-Winters (MHW) and Additive Holt-Winters (AHW). The formula of Multiplicative Holt-Winters (MHW) is elaborated in the following equation [6]:

\[
L_t = \alpha \left( \frac{Y_t}{S_{t-s}} \right) + (1 - \alpha) (L_{t-1} + b_{t-1})
\]

(4)

\[
b_t = \beta (L_t - L_{t-1}) + (1 - \beta) b_{t-1}
\]

(5)

\[
S_t = \gamma \left( \frac{Y_t}{L_t} \right) + (1 - \gamma) S_{t-s}
\]

(6)

\[
F_{t+m} = (L_t + b_t m) S_{t-s+m}
\]

(7)

and Additive Holt-Winters:

\[
L_t = \alpha (Y_t - S_{t-s}) + (1 - \alpha) (L_{t-1} + b_{t-1})
\]

(8)

\[
b_t = \beta (L_t - L_{t-1}) + (1 - \beta) b_{t-1}
\]

(9)

\[
S_t = \gamma (Y_t - L_t) + (1 - \gamma) S_{t-s}
\]

(10)
$F_{t+m} = L_t + b_t + S_{t-s+m}$ \hspace{1cm} (11)

where:

$Y_t$ = data on $t$ time,
$s$ = the seasonal length in a certain time,
$m$ = the amount of data to be predicted.

1.3. $\alpha$-Sutte Indicator

$\alpha$-Sutte Indicator is the development of Sutte Indicator that was developed in 2015 by Ahmar[7]. Sutte Indicator initially developed for predicting the movement of stock [8], [9]. Along with its time development and needs, Sutte Indicator is developed to be $\alpha$-Sutte Indicator [1][10]. The development is expected to provide a better accuracy level and not only limited to the prediction of stock movement but also predict the time series of data. The development of this $\alpha$-Sutte Indicator considers the trend of certain data. Moreover, the formula of $\alpha$-Sutte Indicator is as follows.

$\alpha_t = \frac{\Delta x}{\alpha + \delta} + \beta \frac{\Delta y}{\beta + \alpha} + \gamma \frac{\Delta z}{\gamma + \beta}$ \hspace{1cm} (12)

Where:

$\delta = a_{t-4}$
$\alpha = a_{t-3}$
$\beta = a_{t-2}$
$\gamma = a_{t-1}$
$\Delta x = \alpha - \delta = a_{t-3} - a_{t-4}$
$\Delta y = \beta - \alpha = a_{t-2} - a_{t-3}$
$\Delta z = \gamma - \beta = a_{t-1} - a_{t-2}$
$a_t = \text{series observations at } t \text{ time}$
$a_{t-k} = \text{series observations at } (t - k) \text{ time}$

2. Method

The data that used in this study is the data of Infant Mortality Rate for China (Units: Number per 1,000 Live Birth, Annual, Not Seasonally Adjusted) which is obtained from World Bank (https://fred.stlouisfed.org/series/SPDYNIMRTINCHN). This data began in 1992-2017 with the amount of data as much as 1323. This data is divided into 2 parts of training data as much as 1316 data and test data of 7 data. This data will be forecasted by using ARIMA, HoltWinters, and $\alpha$-Sutte Indicator methods. To see the accuracy of the $\alpha$-Sutte Indicator, it will compare the value of its accuracy with other methods by looking at the value of MSE and MAPE.

3. Results and Discussion

The first step is to do plotting data. Plotting data is used to see trend in a data.
Based on Figure 1 it is seen that the data of Infant Mortality Rate for China tends to decrease. The next step is to forecast data using ARIMA, Holt Winters, and $\alpha$-Sutte Indicator. To simplify the forecasting, it will use Software R statistical assistance in conducting analysis. Forecasting ARIMA uses the autoarima functionality of the forecast package, forecasting the Holt Winters method using the Holt-Winters function of the stats package, and the $\alpha$-Sutte Indicator using the alpha.sutte function of the sutteForecastR package. The results of the analysis as follows:

$autoarima$

Series: al_mi_10
ARIMA(2,2,2)

Coefficients:
  ar1     ar2     ma1     ma2
1.2459 -0.4556 -0.8100  0.7082
s.e.  0.2749   0.2601   0.2348  0.1413
sigma^2 estimated as 0.01825:  log likelihood=-23.7
AIC=-37.39  AICc=-35.52  BIC=-29.2

$holtwinters$

Holt-Winters exponential smoothing with trend and without seasonal component.

Call:
HoltWinters(x = al_mi_10, gamma = FALSE)

Smoothing parameters:
  alpha: 1
  beta : 1
  gamma: FALSE

Coefficients:
   [,1]
a   15.8
b  -1.4

Based on the analysis results obtained that the ARIMA model is ARIMA(2,2,2) and Holt-Winters model with $\alpha$ and $\beta$ are 1.

The results of forecasting as follows:

$test_data$
[1] 14.6 13.5 12.5 11.5 10.6  9.8  9.2

$forecast_alpha_sutte$
[1] 14.362570 13.289812 12.316608 11.442963 10.507730  9.672260  8.936564

$forecast_autoarima$

  Point Forecast  Lo 80  Hi 80   Lo 95  Hi 95
41  14.478016 14.3048953 14.65114 14.213251 14.74278
42  13.151036 12.6951834 13.60689 12.453870 13.84820
43  11.782290 10.8545483 12.71003 10.363432 13.20115
$$\text{Table 1. The results of forecasting data infant mortality rate for China 2011-2017}$$

| Years | Data       | $\alpha$-Sutte Indicator | ARIMA(2,2,2) | Holt Winters |
|-------|------------|---------------------------|--------------|--------------|
| 2011  | 14,60000   | 14,362570                 | 14,478020    | 14,40000     |
| 2012  | 13,50000   | 13,289810                 | 13,151040    | 13,00000     |
| 2013  | 12,50000   | 12,316610                 | 11,782290    | 11,60000     |
| 2014  | 11,50000   | 11,442960                 | 10,363780    | 10,20000     |
| 2015  | 10,60000   | 10,507730                 | 8,902301     | 8,80000      |
| 2016  | 9,80000    | 9,672260                  | 7,409952     | 7,40000      |
| 2017  | 9,20000    | 8,936564                  | 5,898720     | 6,00000      |

To see the level of accuracy it will be compared the value of MSE and MAPE forecasting results from each model.

$$\text{Table 2. Comparison of data forecasting accuracy rate}$$

| Level of Accuracy | $\alpha$-Sutte Indicator | ARIMA(2,2,2) | Holt Winters |
|-------------------|---------------------------|--------------|--------------|
| MSE               | 0.03                      | 3.06         | 3.15         |
| MAPE              | 1.45                      | 13.62        | 14.26        |

4. Conclusion
Based on the results and discussion found that the $\alpha$-Sutte Indicator method is more accurate than ARIMA(2,2,2) and Holt Winters in forecasting data of Infant Mortality Rate for China. It can be seen from the value of MSE and MAPE value of $\alpha$-Sutte Indicator method is smaller than ARIMA(2,2,2) and Holt Winters. This is indicate that $\alpha$-Sutte Indicator more suitable to forecasting infant mortality rate. Based on this result, the government of China can make decision about the infant mortality for next years.

Acknowledgement
The study is partially funded by United States Agency for International Development (USAID) through Sustainable Higher Education Research Alliance (SHERA) Program, Grant No. AID-497-A-16-00004 for Universitas Indonesia, entitled: Scientific Modeling, Application, Research, and Training for City-Centered Innovation and Technology (SMART CITY), Sub-Grant No. IIE00000078.
References

[1] Ahmar A S, 2018 A Comparison of α-Sutte Indicator and ARIMA Methods in Renewable Energy Forecasting in Indonesia Int. J. Eng. Technol. 7, 1.6 p. 20–22.

[2] Ahmar A S et al., 2018 Modeling Data Containing Outliers using ARIMA Additive Outlier (ARIMA-AO) J. Phys. Conf. Ser. 954, 1 p. 01010.

[3] Rahman A and Ahmar A S, 2017 Forecasting of primary energy consumption data in the United States: A comparison between ARIMA and Holter-Winters models in AIP Conference Proceedings 1885.

[4] Surahman Viddy A Gaffar A F O Haviluddin and Ahmar A S, 2018 Selection of the best supply chain strategy using fuzzy based decision model Int. J. Eng. Technol. 7, 2.2.

[5] Haviluddin Agus F Azhari M and Ahmar A S, 2018 Artificial Neural Network Optimized Approach for Improving Spatial Cluster Quality of Land Value Zone Int. J. Eng. Technol. 7, 2.2 p. 80–83.

[6] Ahmar A S Guritno S and Abdurakhman, 2013, Pendeteksian dan Pengoreksian Data yang Mengandung Additive Outlier (AO) pada Model ARIMA(p,d,q), Gadjah Mada University.

[7] Wei W W S, 2006 Time Series Analysis: Univariate and Multivariate Methods 2nd ed. New York, NY: Pearson Addison Wesley.

[8] Ferbar Tratar L and Strmčnik E, 2016 The comparison of Holt–Winters method and Multiple regression method: A case study Energy 109, Supplement C p. 266–276.

[9] Ahmar A S, 2015, Sutte Indicator. [Online]. Available: https://ssrn.com/abstract=2846923. [Accessed: 14-Apr-2016].

[10] Ahmar A S Rahman A Arifin A N M and Ahmar A A, 2017 Predicting movement of stock of “Y” using sutte indicator Cogent Econ. Financ. 5, 1.

[11] Ahmar A S, 2017 Sutte Indicator: an Approach to Predicting the Direction of Stock Market Movement Songklanakarin J. Sci. Technol.

[12] Ahmar A S Rahman A and Mulbar U, 2018 α- Sutte Indicator: a new method for time series forecasting J. Phys. Conf. Ser. 1040, 1 p. 012018.