Forecasting Human Development Index with Double Exponential Smoothing Method and Acorrect Determination

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Abstract

Human development is now seen as a measure of the success of the development of a nation which is closely related to the economic, social, cultural, political and environmental fields. The success of human development is measured based on the Human Development Index (HDI). Boyolali Regency is one of the regencies in Central Java Province which has diverse and abundant natural resources. The large potential of natural resources owned should be in line with the quality of human development. However, it turns out that this is not in line with the HDI value of Boyolali Regency which is still below the average HDI value of Central Java. So that the Boyolali government continues to strive to maximize the potential and increase the HDI value. Based on this, it is necessary to do forecasting as a reference to maximize the level of human development in Boyolali Regency in the next few years. In this study, HDI forecasting in Boyolali Regency was carried out using the Double Exponential Smoothing method from Brown with the data used is HDI data in Boyolali Regency from 2011 to 2021. The data used was obtained from the Central Statistics Agency of Boyolali Regency. HDI forecasting was also carried out using the arithmetical method, and the best forecasting results were compared between the two methods based on the mean absolute percentage error (MAPE). Forecasting results using the Double Exponential Smoothing method produce the best alpha smoothing parameter values of 0.91 and MAPE values of 0.4061%. Meanwhile, using the arithmetic series method, the MAPE is 0.4704%. Both methods produce MAPE values with very good criteria, so that both methods can be used for forecasting. However, based on the criteria for the smallest MAPE value, the Double Exponential Smoothing method is used. The results of the HDI forecasting using the Double Exponential Smoothing method for 2022, 2023 and 2024 are 74.61, 74.81 and 75.02 respectively. While the results of forecasting with arithmetical method for the same years are 74.93, 75.45, and 75.98.

Keywords: arithmetic series, arithmetic series, smoothing constant, MAPE, method, trend.

1. Introduction

Development is one of the nation's means to achieve national goals, and the level of economic growth is a measure of the success of nation-building. In developing countries, high economic growth is the main goal of developing countries like Indonesia.

Human development is a concept that promotes physical and mental improvement in the quality of one's life based on development. Human resources, where necessary, increase the basic capacity of the population to participate in the process of sustainable development (Omer, 2008; Ungar & Theron, 2020; Mohiuddin, et al., 2022). The goal of human development is to increase human freedom, help people to get and enjoy more opportunities, use these skills, so that people can live with dignity, awareness and have access to a better life.

The United Nations Development Program (UNDP) provides a benchmark for assessing the success of human development, namelyusing the Human Development Index (HDI) (Syofya, 2018). The Human Development Index (HDI) was first introduced in 1990 by Amartya Sen, a Nobel laureate from India and Mahbub Ul Haq, a Pakistani economist, and assisted by Gustav Ranis from Yale University and Lord Merghnad Desai from the London School of Economics.

Values for HDI range from 0 to 100. If the HDI value is greater or close to 100, this value indicates a better level of human development (Anand & Sen, 2000; Ravallion, 2010). Based on the HDI value, UNDP categorizes the level of

development in humans into four groups, namely low if the HDI value is less than 60, medium or medium if the HDI value ranges from 60 to 70, high if the HDI value is more than 70, and very high if the HDI value over 80.

Boyolali Regency is one of the areas in Central Java Province which has diverse and abundant natural resources. The large potential of natural resources must be balanced with the quality of human development. However, this turned out to be inconsistent with the Boyolali Regency HDI which was below the Central Java HDI average. Therefore, the Boyolal Government must continue to strive to maximize the potential and increase the HDI value. Based on this, it is necessary to make predictions as a reference to maximize human development in Boyolali's territory for the future. Various forecasting methods can be used to predict the Boyolali District Human Development Index. One of the forecasting methods is the Exponential Smoothing method.

There are three types of exponential smoothing methods, namely the Single Exponential Smoothing, Double Exponential Smoothing, and Triple Exponential Smoothing methods (Karmaker, 2017; Bergmeir, et al., 2016). This Exponential Smoothing method uses parameters of each type, where the most optimal parameter and has the smallest error (error value) will be selected to determine the best forecasting results.

The data used in this report is data on the Boyoali Regency Human Development Index from 2011 to 2021, based on this data there is an upward trend and there is no seasonal pattern. Therefore, one method that can be used is the Doulbe Exponential Smoothing method from Brown.

Several studies have used the exponential smoothing method, including Wijoyo et al. (2022) who predicted the Human Development Index (HDI) for Bojonegoro Regency using the Double Exponential Smoothing method Brown, Zhang et al. (2018) who compared Double Moving Averages with Double Exponential Smoothing in forecasting medical consumables, and Dharmawan et al. (2021) who predicted the level of cocoa production in 2021 in North Sumatra Province using the Double Exponential Smoothing Brown method.

Based on this, the authors are interested in predicting the human development index in Boyolali Regency using Brown's Double Exponential Smoothing method. Furthermore, from the observation of the HDI data, the modeling or forecasting of the data can be done by arithmetical or arithmetic series. Therefore, in this paper two methods are used to forecast HDI data and the best method is selected based on the criteria for the smallest MAPE value. This research is expected to be taken into consideration for the government so that they can make decisions and plan strategies to improve human development.

2. Research Method

2.1. Research steps

Good forecasting is forecasting that is done by following the steps or good preparation procedures. Forecasting can be done with the following steps:

1. Create and analyze time series data plots on the Boyolali Regency human development index data from 2011 to 2021.
2. Determine the forecasting method used based on the results of analysis of time series data plots.
3. Calculating the forecasting parameters on the method that has been determined.
4. Selecting the best forecasting parameters in a predetermined method based on the results of the smallest forecasting error.
5. Calculating the parameter constant values and then calculating the forecasting of the Boyolali Regency human development index with the method that has been determined based on the best parameter values that have been selected.
6. In the arithmetic series method, the difference between data is determined as the average of the difference in the entire data. Meanwhile, the first term of the arithmetic series uses the first data of HDI.

2.2. Data

The data used by the author in this field work practice report comes from the Central Statistics Agency of Boyolali Regency, namely data on the Boyolali Regency human development index from 2011 to 2021 in Table 1.

Table 1. Data on the Boyolali Regency Human Development Index for 2011-2021

Year	HDI
2011	69.14
2012	69.51
2013	69.81
2014	70.34
2015	71.74
2016	72.18
2017	72.64
2018	73.22
2019	73.80
2020	74.25
2021	74.40

2.3. Research Tools and Materials

In this study, Microsoft Excel software was used to calculate the forecasting human development index for Boyolali Regency from 2022 to 2024 using Brown's Double Exponential Smoothing method. The materials used in this research are data, articles, journals, and other references.

3. Results and Discussion

3.1. Purpose of Forecasting

The purpose of this forecasting is to predict the human development index in Boyolali Regency from 2022 to 2024 using human development index data for Boyolali Regency from 2011 to 2021.

3.2. Time Series Data Plots

The first step in forecasting using time series data is to create and analyze time series plots. After observing the pattern of the time series plot, it can be determined which method is suitable for forecasting data based on the pattern of time series data obtained. The Figure 1 following is a time series plot graph of the human development index data for Boyolali Regency from 2011 to 2021 using Microsoft Excel software.
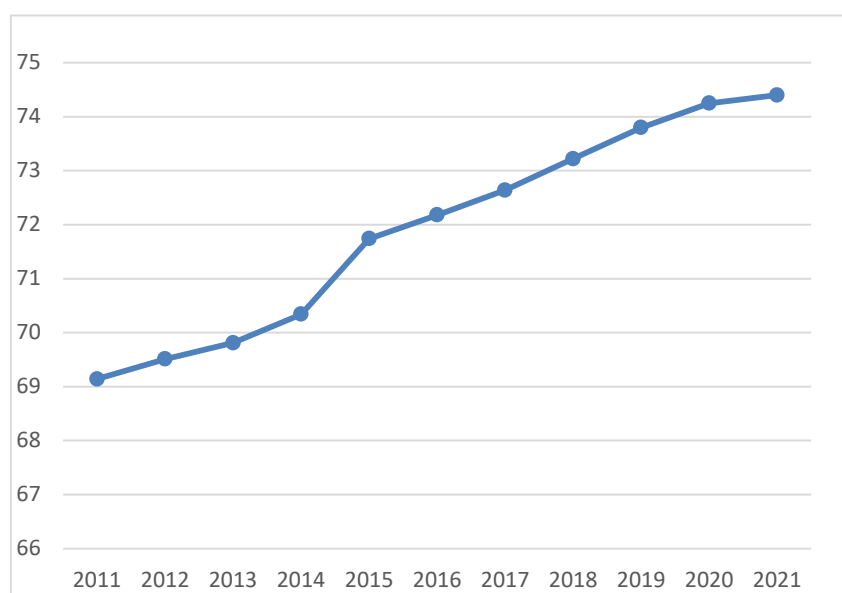

Figure 1. Time series plot for Boyolali Regency HDI data for 2011-2021

Based on the time series plot graph, it can be seen that the human development index data for Boyolali Regency from 2011 to 2021 has an upward trend. So, it can be concluded that the human development index data for Boyolali Regency from 2011 to 2021 has a trend pattern, so the data does not have a horizontal pattern or the data is not constant and the data also does not have a seasonal pattern.

3.3. Selection of Forecasting Methods

Based on the time series data plot, the data shows an upward trend pattern. The Single Exponential Smoothing method is considered incompatible with the data, because the Single Exponential Smoothing method is more suitable for use if the data plot has a horizontal pattern and the Single Exponential Smoothing method is used to predict one period into the future, whereas in this fieldwork practice report the author wants to predict for three next year (three periods). Then the Triple Exponential Smoothing method is also considered not suitable for the data, because there is no seasonal pattern in the data plot. Therefore, with the existence of a trend pattern and the absence of horizontal patterns and seasonal patterns, it can be concluded that the forecasting method that is suitable for predicting the population development index of Boyolali Regency is Brown's Double Exponential Smoothing method.

3.4. Determining Forecasting Parameters

The next step is to determine the best forecasting parameters. In the human development index data for Boyolali Regency, forecasting will be carried out using Brown's Double Exponential Smoothing method, where Brown's Double Exponential Smoothing method uses one parameter, namely alpha (α). The best alpha or parameter value is determined by comparing the errors of the parameters and selecting the parameter or alpha value that has the smallest error value. So to calculate the value of forecasting error used the calculation of the average absolute percentage error or mean absolute percentage error (MAPE).

The parameters used in forecasting using the Double Exponential Smoothing method from Brown are an alpha value of 0.1; 0.2; 0.3; 0.4; 0.5; 0.6; 0.7; 0.8; 0.9; 1.0. The following is the result of calculating the MAPE value in the Double Exponential Smoothing method using Microsoft Excel software.

Table 2. MAPE values using the Double Exponential Smoothing method

Smoothing Constant α	MAPE Value
0.10	2.5309%
0.20	1.3844%
0.30	0.8367%
⋮	⋮
0.90	0.4062%
0.91	0.4061%
0.92	0.4071%
0.93	0.4080%
0.94	0.4087%
0.95	0.4092%
0.96	0.4096%
0.97	0.4098%
0.98	0.4098%
0.99	0.4100%

3.5. Selection of the Best Parameters

The best parameter is the parameter that can minimize the error value in the data forecasting calculation process. Because the smaller the error value in a data, the higher the level of accuracy of a data. Based on Table 2, it can be seen that the smallest MAPE error value is found at an alpha value of 0.91, so to predict the human development index for Boyolali Regency for the next three periods an alpha parameter of 0.91 is used.

3.6. Forecasting HDI with the Double Exponential Smoothing Method

After selecting the best parameters, the next step is to calculate the human development index forecast for Boyolali Regency for the next three years (three periods) using the Brown's Double Exponential Smoothing method with an alpha parameter of 0.91. The calculation steps are as follows:

1. Determine the Single Exponential Smoothing value
   $$S'_t = 0.91 \ X_t + (1 - 0.91)S'_{t-1}$$
2. Determines the Double Exponential Smoothing value
   $$S''_t = 0.91 \ S'_t + (1 - 0.91)S''_{t-1}$$
3. Determine the value of the trend coefficient
   $$a_t = 2S'_t - S''_t$$
4. Determine the value of the smoothing constant
   $$b_t = \frac{0.91}{1-0.91}(S'_t - S''_t)$$
5. Foresee the coming period
   $$F_{t+m} = a_t + b_t(m)$$

The following is Table 3 for the results of calculations using Microsoft Excel software. Next, the prediction of the Boyolali Regency human development index is calculated for three periods from 2022 - 2024. Using the results of the constant values a_t and b_t that have been obtained, the equation becomes.

$$F_{t+m} = \ 74.40262 + 0.204505(m)$$

Table 3. Calculation results for the value of Single Exponential Smoothing,

Period	Year	HDI	Single Exponential Smoothing S'	Double Exponential Smoothing S''	Smoothing Constant a_t	Trend Coefficient b_t
1	2011	69.14	69.14000	69.14000		
2	2012	69.51	69.47670	69.44640	69.50700	0.306397
3	2013	69.81	69.78000	69.74998	69.81003	0.303581
4	2014	70.34	70.28960	70.24103	70.33817	0.491056
5	2015	71.74	71.60946	71.48631	71.73262	1.245271
6	2016	72.18	72.12865	72.07084	72.18646	0.584535
7	2017	72.64	72.59398	72.54690	72.64106	0.476056
8	2018	73.22	73.16366	73.10815	73.21917	0.561253
9	2019	73.80	73.74273	73.68562	73.79984	0.577468
10	2020	74.25	74.20435	74.15766	74.25103	0.472043
11	2021	74.40	74.38239	74.36217	74.40262	0.204505

Then, after obtaining a forecasting model to predict the human development index for Boyolali Regency for the next three years, the human development index forecast for 2022 - 2024 is obtained as follows:

Period 12 (year 2022)

$$F_{11+1} = 74.40262 + 0.204505(1)$$
$$F_{12} = 74.60712$$

In the same way, F_{13}=74.81163 and F_{14}=75.01613 are obtained. The results of forecasting the Boyolali Regency Human Development Index using the Double Exponential Smoothing method for the next three years are available in Table 4.

Table 4. Forecasting Results of the Boyolali Regency HDI for 2022 – 2024 with Double Exponential Smoothing Method

Periode	Year	Forecasting
12	2022	74.61
13	2023	74.81
14	2024	75.02

Based on Table 4, it can be seen the results of forecasting the human development index for Boyolali Regency from 2022 to 2024 using the Double Exponential Smoothing method with a forecasting parameter value of 0.91, increasing every year. Next, a data plot will be carried out based on the forecasting value of the human development index in Boyolali Regency from 2011 to 2024.

3.7. HDI Forecasting with Arithmetical Method

Next, the prediction of the human development index for Boyolali Regency for the next three years will be calculated using arithmetic progression. In forecasting calculations using arithmetic progression for the Boyolali District Human Development Index, the *b* value obtained is 0.526 and the *a* value is 69.14. The *b* value is obtained by finding the average value of each difference in the Boyolali Regency human development index data in Table 5. The *a* value in this calculation is obtained by looking for the initial value in the Boyolali Regency human development index data.

Table 5. Value Calculation Results *b*

HDI	value *b*
69.14	
69.51	0.37
69.81	0.30
70.34	0.53
71.74	1.40
72.18	0.44
72.64	0.46
73.22	0.58
73.80	0.58
74.25	0.45
74.40	0.15
average	0.526

After getting the results for values *a* and *b*, forecasting calculations are then carried out with an arithmetic series using Microsoft Excel software. The results of forecasting calculations using an arithmetic series can be seen in Table 6. Based on Table 6, the results of forecasting the human development index in Boyolali Regency using an arithmetic series and the MAPE value obtained is 0.4704%.

Table 6. Forecasting Results with Arithmetic Series

Period	Year	HDI	Forecasting	MAPE
1	2011	69.14	69.140	0.0000%
2	2012	69.51	69.666	0.2244%
3	2013	69.81	70.192	0.5472%
4	2014	70.34	70.718	0.5374%
5	2015	71.74	71.244	0.6914%
6	2016	72.18	71.770	0.5680%
7	2017	72.64	72.296	0.4736%
8	2018	73.22	72.822	0.5436%
9	2019	73.80	73.348	0.6125%
10	2020	74.25	73.874	0.5064%
11	2021	74.40	74.400	0.0000%

Next, forecasting the Boyolali Regency Human Development Index for the next three years will be carried out using the equation:

$$U_n = a + (n-1).b$$

The results of forecasting the Human Development Index for the years 2022 - 2024 are as follows:

Period 12 (year 2022)

$$U_{12} = 69.14 + (12-1) \times 0.526$$
$$U_{12} = 74.926$$

In the same way $U_{13} = 75.452$ and $U_{14} = 75.978$ are obtained. Full results are provided in Table 7.

Table 7. Forecasting Results of HDI for Boyolali Regency 2022 - 2024 with Arithmetic Series

Periode	Year	Forecasting
12	2022	74.93
13	2023	75.45
14	2024	75.98

Based on Table 3, Table 4, Table 6 and Table 7, the results of the forecasting of the Boyolali Regency Human Development Index using the Double Exponential Smoothing method and the arithmetic series are graphed in Figure 2. The graphs of the two forecasting results show an upward trend and this trend is in accordance with the research data. The forecast results for 2022, 2023 and 2024 show that the HDI values obtained by arithmetic progression are higher than the Double Exponential Smoothing method.

Forecasting results using the Double Exponential Smoothing method produce the best alpha smoothing parameter values of 0.91 and MAPE values of 0.4061%. Meanwhile, using the arithmetic series method, the MAPE is 0.4704%. Both methods produce MAPE values with very good criteria, so that both methods can be used for forecasting. However, based on the criteria for the smallest MAPE value, the Double Exponential Smoothing method is used. The results of the HDI forecasting using the Double Exponential Smoothing method for 2022, 2023 and 2024 are 74.61, 74.81 and 75.02 respectively. While the results of forecasting with arithmetical method for the same years are 74.93, 75.45, and 75.98.
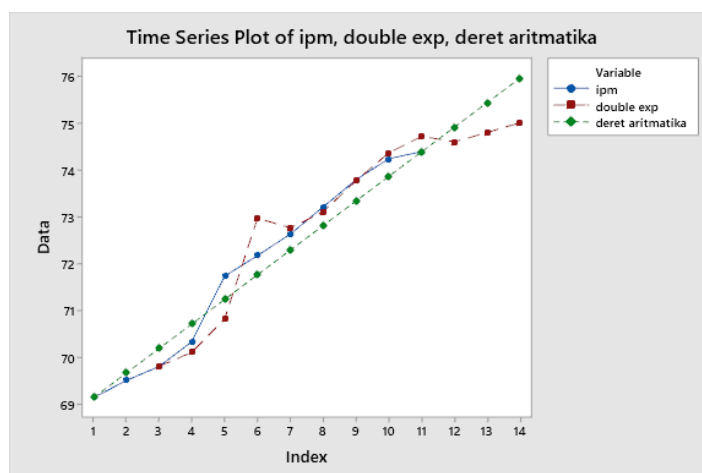

Figure 2. Graph of Comparison of Research Data with Forecasting Result Data

4. Conclusions And Suggestions

The Double Exponential Smoothing and Arithmetic Series methods used in forecasting the HDI data for Boyolali Regency give a MAPE value with very good criteria. Thus, both methods can be used for forecasting. However, based on the smallest MAPE criteria, the Double Exponential Smoothing method is more recommended for use in forecasting HDI in Boyolali Regency in the following three-year period.

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