Autocorrelation analysis of COVID-19 based on hijri calendar

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Abstract. Indonesia is a country with a majority of Muslims. The Covid-19 outbreak to Indonesia concerns moments during Islamic holidays. There are many Islamic holidays from March to July, such as Ramadhan, Shawwal, and Eid al-Adha. This study aimed to investigate the relationship between after and before Covid-19 case (lag 1). This study also discussed the relationship among three cases per month for both calendars (Islamic and Gregorian calendar). Auto conversion data from daily to monthly of Hijri and Gregorian was compared by determining the autocorrelation on three cases (confirmed, recovered, and death cases) in both calendars. The auto-correlation test using the Islamic month had 0.747 confirmed cases, 0.711 recovered cases, and 0.461 death reported cases. In the meantime, auto-correlation test using Gregorian month had 0.013 confirmed cases, 0.085 recovered cases, and -0.203 death cases. We also calculated the monthly autocorrelation of Covid1-9 cases from March to August 2020; the result showed that autocorrelation values were high for both calendars. However, the value of autocorrelation from March to August, Gregorian calendar is higher than Hijri calendar.

1. Introduction
On December 31, 2019, this year's Wuhan Municipal Health Commission broadcast a number of these pneumonia etiological events that had occurred in this city\cite{1}. This disease is a contagious and pathogenic virus\cite{2}. This year's World Health Organization (WHO) report that Covid-19 must have been a global epidemic, unregulated transmission causes a significant number of cases in almost all countries, including Indonesia. The Covid Task Force on Covid-19 reported 33,076 positive people infected with Covid-19, 11,414 were cured, and 1,923 died. Based on these results, Indonesia is the second-highest case of infection in South East Asia after Singapore, with the highest distribution of Covid-19 cases in Jakarta and East Java Province.

As the highest Muslim country globally, Indonesia celebrates the Islamic month that influences the Covid-19 outbreak. For Muslims, Ramadhan and Shawwal are months full of ritual and non-ritual worship, such as Tarawih, Eid al-Fitr, and going home to hometown. These activities are very risky if carried out during the outbreak of Covid-19, as the spread of Covid-19 occurs within a short distance from one person to another. The month of Ramadhan when Muslims observe their worship more frequently than in other months. In particular, worship in a congregation such as Tarawih and Eid prayer.
Moreover, the practice of Eid, such as going home amongst relatives and even shopping at the market or the Mall more frequently than other months that significantly increases the risk of Covid-19.

Many studies on Covid-19 in Indonesia have been carried out, including in education [3], [4] and [5], economics [6] and [7] environments [8] and [9], as well as math and statistics [10], [11], [12], reviewed the analysis of Covid-19 in Indonesia [13]. However, many of these studies usually hold the Gregorian calendar for analysis. Here, in this paper, we propose a Hijri calendar for analyzing the Covid-19 in Indonesia.

The use of the Hijri month in research has been carried out by many researchers. Gregorian conversion to other calendars had been proposed, Conversion Novel algorithm for conversion Gregorian to Khayyami calendars [14]. Another study investigated solar and lunar motion in the Chongxiu-Daming (CD) calendar by analyzing the calculation methods of sunrise and sunset times, solar and lunar uneven motion, and maximum solar eclipse time [15]. They examined at Islamic monthly anomalies in the stock market in a Muslim country – Pakistan[16]. Another study suggested empirical arithmetical formula of leap or a non-leap year in the Islamic calendar [17] and also suggested that Farewell Hajj of the Prophet Mohammad be the basis of this calendar (Islamic Calendar) [18].

In this study, Indonesia's Covid-19 data are added every month from March to August. Covid-19 data is converted into a monthly Hijri calendar. The autocorrelation results of the two calendars were compared to see the trend of the spread of Covid-19 in Indonesia in terms of the month. Calculating the correlation value of the covid19 data associated with the month was carried out to see whether the moment of the Islamic month celebration affected the spread of Covid-19 in Indonesia.

2. Methods
When converting data from the daily Gregorian calendar to the monthly Hijri calendar, segmentation of conversion processes is required. The division into three segments was performed to simplify the coding process in addition to the conversion segment because the date from the Hijri calendar to the Gregorian calendar is different in the process. For example, on the Gregorian calendar, January 1 will not fall exactly to 1 Muharram on the Hijri calendar, and vice versa.

The three segments are the first-year, middle-year, and end-of-year segments. The first year segment is the first part of the date converted to the end of Hijri period (29 Dzulhijjah). The middle year segment is a segment that starts at the beginning of Muharram until the end of Dzulhijjah. This segment is the simplest time zone to be determined due to the completed full form of Hijri calendar from Muharram to Dzulhijjah. The end-of-year segment starts from Muharram to the end of the determined calendar. Algorithm for automatic Hijri calendar conversion contained:

1. Specify the start and end dates of the calendar created.
2. Divide into three calendar segments, namely the first year, the middle calendar, and the End of the year.
3. Convert the boundary points to the Islamic calendar and Hijri (step 2).
4. Make a three-segment vector for both the Gregorian calendar and the Hijri and calendar attributes, i.e. the date and number of Hijri.
5. Combine the three vectors in a data frame.
6. Input daily data that will be converted to Hijri data in a single column/vector.
7. Combine the daily data (step 7) with the data frame (step 6) in a data frame that is ready to be converted.
8. Modification of TS Syntax in R-software with the name of Hijri months and time limits according to the data to be converted.

The covid-19 monthly data, both the Gregorian calendar and the Hijri calendar, are determined by the autocorrelation[19] value with the following equation;

$$\hat{\rho}_k = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(x_{i+k} - \bar{x})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}}, k = 0, 1, 2, ..., (1)$$
Where $\bar{X}_n = \frac{1}{n} \sum_{i=1}^{n} X_i$ the sample means of the series. A plot of $\hat{\rho}_k$ versus k (lag) is sometimes called a sample correlogram.

3. Results and Discussion
The data conversion followed the steps in section 2 above, then specified the start and end date to be converted. Here, the initial data conversion is from March 2 to August 31, 2020. The data conversion used R-software; daily data was added up monthly. The sum of the data followed the calculation of the months of AD and the months of Hijri. The results can be seen in tables 1 and 2.

After converting the data daily to monthly, the number of confirmed, recovered, and death cases were determined per month based on two calendars. The first calendar is the Gregorian calendar from March to August. The second calendar is Hijri calendar from Rajab to Muharram. The autocorrelation calculation of each case was carried out for two periods. The first period is from March 2 to July 6, 2020 (Table 1), while the second period is from March 2 to August 31, 2020 (Table 2).

Table 1. Covid-19 case on Period 1

| Calendar | Month | Confirmed Case | Recovered Case | Death Case |
|----------|-------|----------------|----------------|------------|
| Gregorian | March | 1528          | 81             | 136        |
|          | April | 8590          | 1441           | 656        |
|          | May   | 16355         | 5786           | 821        |
|          | June  | 29912         | 17498          | 1263       |
|          | July  | 8573          | 5113           | 365        |
|          | Rajab | 790           | 31             | 58         |
|          | Sya'ban | 6985         | 929            | 589        |
|          | Ramadhan | 13970        | 4289           | 704        |
| Hijri    | Rajab | 790           | 31             | 58         |
|          | Sya'ban | 6985         | 929            | 589        |
|          | Ramadhan | 13970        | 4289           | 704        |
|          | Shawwal | 24146        | 13155          | 1114       |
|          | Dzulqaidah | 43978      | 30062          | 1855       |
|          | Dzulhijjah | 19067      | 11515          | 776        |

For the Gregorian calendar, the autocorrelation value (lag 1) was obtained using equation 1, resulting in 0.01 confirmed cases, 0.08 recovered cases and -0.203 death cases. For the Hijri calendar, the autocorrelation value (lag 1) after using equation 1 resulted in 0.747 confirmed cases, a 0.711 recovered case, and a 0.461 death case.

Table 2. Covid-19 cases on Period 2

| Calendar | Month | Confirmed Case | Recovered Case | Death Case |
|----------|-------|----------------|----------------|------------|
| Gregorian | March | 1528          | 81             | 136        |
|          | April | 8590          | 1441           | 656        |
|          | May   | 16355         | 5786           | 821        |
|          | June  | 29912         | 17498          | 1263       |
|          | July  | 8573          | 5113           | 365        |
|          | August | 66420       | 60052          | 2286       |
|          | Rajab | 790           | 31             | 58         |
|          | Sya'ban | 6985         | 929            | 589        |
|          | Ramadhan | 13970       | 4289           | 704        |
| Hijri    | Shawwal | 24146        | 13155          | 1114       |
|          | Dzulqaidah | 43978      | 30062          | 1855       |
|          | Dzulhijjah | 57342      | 52208          | 2098       |
|          | Muharram | 30360       | 27383          | 1087       |

For the Gregorian Calendar, the autocorrelation value (lag 1) obtained using equation 1 had 0.981 confirmed cases, 0.967 recovered cases, and 0.888 death cases. For the Hijri calendar, the autocorrelation value (lag 1) using equation 1 had a 0.688 confirmed case, a 0.659 recovered case, and a 0.630 death case.
From the table, the results of the calculations above show that when there is a major religious holiday in a month, the development of the corona case will follow the Hijri calendar. However, if there is no religious holiday in a month, the corona case's development will follow the Gregorian calendar. The development of corona cases that occurred in one month was influenced quite high by the previous month; this is according to the researchers' findings if a person with Corona will be infected for two weeks starting from the person contaminated with the coronavirus.

Based on the Gregorian calendar, the highest increase in confirmed cases occurred from June to July, totaling 22079 people. Likewise, for Recovered cases and Deaths Cases, respectively 23603 and 992 people. Based on the Hijri calendar, the increase in confirmed cases occurred from the month of Shawwal to Dzulqaidah, which was 19832 people. Likewise, for recovered cases and deaths cases, 22146 and 741 people, respectively.

4. Conclusion

In the first period (March-July or around Rajab-Dzulqaidah), the autocorrelation of Covid-19 data has a high autocorrelation value when using the Hijri calendar. This case happens as March-July are more influenced by Muslim holidays such as Ramadhan, Eid al-Fitr, and Eid al-Adha. From March to August or around Rajab-Muharam, the autocorrelation value of Covid-19 data using the Gregorian calendar is higher than using the Hijri calendar; this is due to people are returning to their activities following the Gregorian calendar. Activities influenced by the AD calendar are shopping at the beginning of the month and opening several educational, recreational, and industrial facilities.

Acknowledgment

We acknowledge the research support PDD 2020 from the Directorate General of Research Enhancement and Development, Ministry of Research Technology and Higher Education, Indonesia.

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