

A Weighted Markov Chain Application to Predict Consumer Price Index When Facing Pandemic Covid-19

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ABSTRACT

Covid-19 is an infectious disease caused by acute respiratory syndrome coronavirus 2 (severe acute respiratory syndrome coronavirus 2 or SARS-CoV-2). It makes the decrease of people's purchasing power. Meanwhile, the economic growth indicates the success of a country's economic development. Therefore, the Consumer Price Index occurs Inflation and Deflation, which is commonly referred to in the economy as the Consumer Price Index. This study aimed to apply a weighted Markov chain method to predict the consumer price index in the future. The satisfactory results obtained by researchers in predicting the consumer price index are in, the chance is 84.34% and the 12th month has a 78.54% chance.

Keywords: Covid-19, Consumer Price Index, Weighted Markov Chain.

INTRODUCTION

Covid-19 is an infectious disease caused by acute respiratory syndrome coronavirus 2 (severe acute respiratory syndrome coronavirus 2 or SARS-CoV-2). This virus is a large family of Coronaviruses that can attack animals. When it attacks humans, Coronavirus usually causes respiratory infections, such as flu, MERS (Middle East Respiratory Syndrome), and SARS (Severe Acute Respiratory Syndrome). Covid-19 is a new type of coronavirus found in Wuhan, Hubei, China in 2019 [1]. Since it has been found, it spreads widely and causes global pandemic that has continued to nowadays. Generally, the symptoms of Covid-19 are getting fever more than 38°C, dry cough, and shortness of breath and the worst impact for humans is death [2].

Lately, Covid-19 has become a big concern of the Indonesian people because of its enormous impact. There are many losses caused by Covid-19 which have an effect on the Indonesian economy. The economic development of a country aims to achieve the prosperity of the people through high economic growth and equitable income distribution. Contrastly, the crisis in Indonesia in 1997/1998 was initially caused by the exchange rate then developed into a banking crisis, spread to social and political problems that had significant impact on the Indonesian nation. The high rate of inflation at that time caused a decrease in people's purchasing power, especially for low-income groups. Changes in the amount of money can affect the interest rate and the consumption function, so the amount of money causes changes in overall demand [3].

Economic growth is a development goal that every country wants to achieve. The economic growth is an indication of the success of a country's economic development. Therefore, every developed and developing country always tries to spur economic growth, which is used to describe the progress or development of the economy in a country [4]. Therefore, the Consumer Price Index occurs Inflation and Deflation which is commonly referred to in the economy as the Index of Consumer Prices. The Consumer Price Index (CPI) is an important economic indicator that can provide information on developments in the price of goods/services paid by consumers in an area.

The biggest economic problem in a country is inflation. Inflation is usually measured using the Consumer Price Index based on the Central Statistics Agency (BPS). The Consumer Price Index (CPI) is defined as an index used to calculate the average price change in a period, from a collection of goods and services consumed by residents and households within a certain period [5].

The Consumer Price Index (CPI) is an important economic indicator that can provide information on developments in the price of goods/services paid by consumers in an area. CPI calculation is intended to determine changes in the price of a fixed group of goods/services that are generally consumed by local people [6].

Table 1. Consumer Price Index Expenditure Group

No	Category	Section Category
1.	Food material	Grains (Tubers), Meat, Fresh Fish, Preserved Fish, Eggs and Milk, Vegetables, Nuts, Fruits, Seasonings, Fats and Oils Other Food Ingredients
2.	Prepared Food, Beverages, Cigarettes and Tobacco	Prepared Food, Non-Alcoholic Beverages, Tobacco and Alcoholic Drinking.
3.	Housing, Water, Electricity, Gas, and Fuel	Housing Costs, Fuel (Lighting), and Water for Household Appliances, Household Operation
4.	Clothing	Men's Clothing, Women's Clothing, Children's Clothing, Personal Items, and Other Clothing
5.	Health	Health Services, Medicines, Physical And Health Care Services
6.	Education, Recreation, and Sports	Educational Services, Courses / Training, Educational Equipment Supplies, Recreation and Sports
7.	Transportation, Communication and Financial Services.	Transport, Communication and Delivery, Transportation Support Facilities, Financial Services

The weighted Markov chain is the Markov chain that changes with improvements, making it possible to explore the impact of the transition probability matrix of each step and the data mining of the initial data [7]. The weighted Markov chain is widely used in the financial world. The weighted Markov chain does not require continuous and long historical data in predicting something, but only needs some recent data. Therefore, the weighted Markov chain can be used to solve various problems in the social and economic fields, one of which is the consumer price index.

From the description above, why the weighted Markov chain method was chosen, it was because the various factors in the average change in the consumer price index constantly change over a period. These changes are often unpredictable, one of which is during the Covid-19 pandemic. Therefore, this study was conducted to predict the Consumer Price Index when Facing the Covid-19 December-September 2020 Pandemic. One method used is to use a weighted Markov chain, then the author takes the title "The Weighted Markov Chain Application to Predict the Consumer Price Index in the face of the Covid-19 Pandemic."

METHOD

Markov chain

Markov chain is a technique used in analyzing the current behavior of several variables to predict the behavior of the same variable in the future [1]. A Markov chain of discrete time is a Markov process whose state space is a finite set with time $T = (0, 1, 2, \dots)$. Markov properties when a formula is formed, the result is

$$P\{X_{n+1} = j | X_0 = i_0, \dots, X_{n-1} = i_{n-1}, X_n = i\} = P\{X_{n+1} = j | X_n = i\}, \quad (1)$$

for all n times and all states $i_0, \dots, i_{n-1}, i, j$ [8].

Basic Markov Chain Theory is Weighted

The weighted Markov process is a theory that primarily studies the state of objects and transition states and describes the process of dynamic change from a random time series. The difference between the weighted Markov chain method and the Markov chain method is the initial state weight. The weight of the initial state is predicted that the Markov chain is weighted not only 1 or 0 but each state is analyzed according to a reasonable calculation formula and the weight is calculated repeatedly [9].

Markov Trait Test

The Markov chain can only be applied to a process if the process has Markov properties. In this case, a Chi-square statistical test will be used to check whether the process has Markov properties or not.

$$\chi^2 = 2 \sum_{i=1}^m \sum_{j=1}^m f_{ij} \left| \ln \frac{\hat{P}_{ij}}{\hat{P}_i} \right| \quad (2)$$

Where f_{ij} is the frequency with which a $\{X_n\}$ process is transitioning one step from state i to state j for n weeks so that f_{ij} can be written as a transition frequency matrix

$$\begin{bmatrix} f_{11} & \cdots & f_{1m} \\ \vdots & \ddots & \vdots \\ f_{m1} & \cdots & f_{mm} \end{bmatrix}. \quad (3)$$

After the χ^2 value is obtained, the value will then be compared with the value χ^2 with degrees of freedom $(m-1)^2$ and significance level α , or it can be written as $\chi^2 \alpha((m-1)^2)$. If value $\chi^2 > \chi^2 \alpha((m-1)^2)$ the process tilapia can be considered to have Markov properties [9].

Calculation of the Weight of the Markov Chain

As previously mentioned, in the weighted Markov chain, the chance that a process will be in a state at a future time is influenced by the states at one time before until the previous time K . Furthermore, the weighting will be carried out for each $K \in \{1, 2, \dots, K\}$. This weighting is useful for describing the portion of each k in predicting Medan's CPI when facing the Covid-19 pandemic. Any weight for each k can be obtained by a formula

$$w_k = \frac{|r_k|}{\sum_{k=1}^K |r_k|} \quad (4)$$

where r_k is the autocorrelation coefficient for each $K \in \{1, 2, \dots, K\}$ which can be obtained through the following formula:

$$r_k = \frac{\sum_{t=1}^{n-k} (X_t - \bar{X})(X_{t+k} - \bar{X})}{\sum_{t=1}^n (X_t - \bar{X})^2} \quad (5)$$

In the above formula X_t is the CPI for Medan City when facing the Covid-19 pandemic in the t week, \bar{X} the average of the Medan City CPI when facing the Covid-19 pandemic, and n is the amount of CPI data for Medan City when facing the Covid-19 pandemic [9].

Prediction Range of Consumer Price Index

After the Markov chain weights have been obtained, the prediction of the future consumer price index can be done using a formula

$$\hat{P}_{ij} = \sum_{k=1}^K w_k \hat{P}_{ij}^{(k)} \quad (6)$$

for every $j \in \{1, 2, \dots, m\}$. \hat{P}_{ij} is the opportunity for the Consumer Price Index to be in state j in the future. The resulting prediction is a state, namely state j at $\max\{\hat{P}_{ij}, j = 1, 2, \dots, m\}$ [9].

Research Methodology

The type of this research is quantitative applied research. A quantitative research method is a type of research whose specifications are systematic, well-planned, and clearly structured from the start to the making of the research design. Therefore, this research describes the Consumer Price Index in Medan that the value constantly changes unpredictably and how to solve the problem using Weighted Markov Chain method.

The data used in this study is secondary data (existing data). The data source used in this study is the Medan City Consumer Price Index data. Data were obtained from the website of the Central Statistics Agency (CSA) in North Sumatra Province. Since this research used secondary data so that there is no criteria, measurement or testing being used yet.

The variable studied is the Consumer Price Index (CPI) from December 2019 to September 2020 at the Central Statistics Agency (CSA) of Medan City with 10 months of historical data and grouped into a state, namely state 1, state 2, and state 3.

Variables:

- X = Consumer Price Index
- m = number of states
- n = lots of data
- \bar{X} = mean of Consumer Price Index
- S = standard deviation of Consumer Price Index
- k = number of case

The research steps for predicting the Consumer Price Index in Medan are as follows:

1. Data Collection
2. Calculation of Average and Standart Deviation
3. Consumer Price Index Grouping
4. Markov Trait Test
5. Markov Chain Weight Calculation
6. Prediction Range of Consumer Price Index
7. Analyze Data
8. Draw Conclusion and Suggestions

RESULTS AND DISCUSSION

The consumer price index data from December 2019 to September 2020 is the data used taken from <https://sumut.bps.go.id/>. There are ten data used with the weighted Markov chain application method. The data were

used to form the model, while the Consumer Price Index data for the next two months, namely October 2020 to November 2020 will be used in the prediction process.

The data will be presented in graphical form, which is more clearly visible from December 2019 to September 2020 in the following figure.

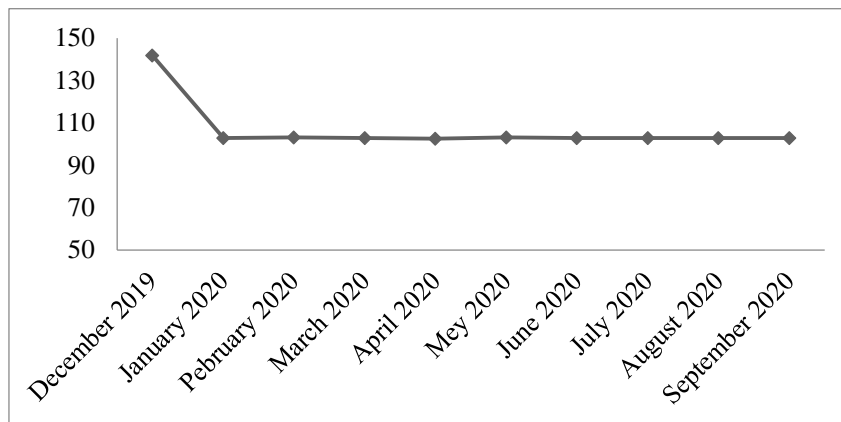


Figure 1. Graph of the Consumer Price Index for the city of Medan

Figure 1 shows a graph of the Consumer Price Index data from December 2019 to September 2020 where inflation (rising) and deflation (falling) in the consumer price index occurred.

Table 2. Cases to be analyzed

Case	Lots of Data (n)	Period	The number of states (m)
	10	December 2019 – September 2020	3

Changes in the consumer price index every month are then grouped based on the average value and the standard deviation has been obtained in the previous step. In this consumer price index problem the researcher can examine 10 data which can only be grouped into 3 states, namely as follows.

Table 3. Grouping the consumer price index

State	Basic Grouping	State limits
1	$X < \bar{X} - 0.3S$	$X < 103.05$
2	$\bar{X} - 0.3S \leq X < \bar{X}$	$103.05 \leq X < 106.76$
3	$X \geq \bar{X} + 0.3S$	$X \geq 110.46$

After consumer price index are grouped in three state, then state transitions can be shown in the Table 4.

Table 4. Consumer Price Index for the period December 2019 to September 2020, state and state transition.

Month	Period	Consumer price index	Case	
			State	State Transition
1	December 2019	141.89	3	
2	January 2020	102.95	1	3_1
3	February 2020	103.09	2	1_2
4	March 2020	102.89	1	2_1
5	April 2020	102.60	1	1_1
6	May 2020	103.03	1	1_1
7	June 2020	102.94	1	1_1
8	July 2020	102.72	1	1_1
9	August 2020	102.76	1	1_1
10	September 2020	102.71	1	1_1

Then from the results, state and state transition the frequency matrix is formed as follows.

$$f_{ij} = \begin{bmatrix} 6 & 1 & 0 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

Applying the Markov chain to a data, the data must meet the Markov properties, the examination is carried out by using the chi-square test, with a value of $\alpha = 5\%$. The following table shows the chi-square value of the cases.

Table 5. Chi-square statistical test in cases

Cases	χ^2	$\chi_{0.05}^2 ((m-1)^2)$	Comparison of Chi-square Values
	13.39	9.488	$\chi^2 > \chi_{0.05}^2 ((m-1)^2)$

Since the value of $\chi^2 > \chi_{0.05}^2 ((m-1)^2)$ in the case, with a probability of error of 5%, the consumer price index can be said to have Markov properties. Therefore, in the Weighted Markov Chain method, it can be used to predict the future Consumer Price Index.

Before calculating the Markov Chain Weight value, the value of the Autocorrelation Coefficient must first be sought in case k. The following is a table of the Autocorrelation Coefficient of the Consumer Price Index with $k = 1, 2, 3$.

Table 6. The value of the autocorrelation coefficient in case k

k	1	2	3	4	5
r_k	-0.0975	-0.061	-0.0991	-0.0514	-0.0505

After the Correlation Coefficient value is obtained, the Markov Chain Weight can be searched, as follows, the Markov Chain Weight value can be seen in the following table.

Table 7. Markov Chain Weights in case k for each $k = 1, 2, 3$.

k	w_k		
	K = 1	K = 2	K = 3
1	1	0.9840	0.8849
2		0.9009	0.8495
3			0.8980

Furthermore, the prediction of the consumer price index range, see the prediction results in the table below.

Based on the results of research, the application of the Weighted Markov Chain predicts the Consumer Price Index when facing the Covid-19 pandemic, the researchers get the Average Consumer Price Index of 106.76 percent and the Standard Deviation of the Consumer Price Index is 12.35 percent, by getting the Average and Standard Deviation of Price Index Consumers can be grouped into 3 states, namely the state 1 with the state limit of X value less than 103.05, the state 2 with the state X limit is greater than 103.05 and X is smaller than 106.76, and the state 3 X is greater equal to 110.46, and the researcher tested the Markov trait by calculating the Chi-square value test on the Consumer Price Index data from December 2019 to September 2020 getting $\chi^2 > \chi_{0.05}^2 ((m-1)^2)$ results, with a probability of error of 5%, which is said to have Markov properties, and calculating the Weight of the Markov Chain by first calculating the Autocorrelation Coefficient to calculate the Markov Chain Weight Price Index a Consumers, then the Markov Chain Weight results can be used to predict the Consumer Price Index Range that gets the prediction results in the following table.

Table 8. Prediction results

Month	Predicted state results	Predicted odds
11	1	84.34%
12	1	78.54%

Based on the prediction results in October 2020 with State 1 is 84.34%, the prediction result in December 2020 with State 1 is 78.54%.

CONCLUSION

The application of the Weighted Markov Chain method to the Consumer Price Index in Medan during the study period shows that the value of the Consumer Price Index in the 11th month is 84.34% and the 12th month has a 78.54% chance, based on the results of the study, satisfactory results can be obtained. The prediction results of the consumer price index when facing the Covid-19 pandemic show that economic conditions in the future will increase.

Based on the results of the research that has been done, the authors suggest to further develop this Weighted Markov Chain Application involving many indicators and related variables to predict the next. The use of the Weighted Markov Chain Application method can also be developed to assist the government or related agencies to analyze future economic developments.

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