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Comparison of Annual Inflation Percentage Prediction in West Java Using Newton-Gregory Forward Interpolation and Cubic Spline

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ABSTRACT

Inflation is the rise in prices of those, fundamental need of society. The occurrence of inflation can be measured by the consumer price index (CPI). The increase in inflation was due to several expenditures based on people's needs. If inflation is high, it can affect competitiveness in the sectors of the industry. The purpose of this study is to compare functions describing the movement of inflation data in West Java using Newton-Gregory Forward Interpolation Method and the Cubic Spline Interpolation Method. Based on the results of the study, it is found that both methods result in smooth functions. However, in the Cubic Spline Interpolation Method there is no significant change in the value of the function/data within each subinterval. Meanwhile, in Newton-Gregory Forward Interpolation, there are significant changes in the value of the function/data between the ends of the right-hand side subintervals. This implies that errors of the function produced by Cubic Spline interpolation are less than those of the other one. Therefore, the Cubic Spline Interpolation Method is better than Newton-Gregory in predicting the inflation percentage data in West Java.

Keywords: Newton-Gregory Forward Interpolation, Cubic Spline Interpolation, Prediction, Inflation

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1. INTRODUCTION

According to the Great Dictionary of the Indonesian Language, inflation is a decline in the value of money (bank notes) due to the amount and velocity of money (bank notes) circulating increase, causing the price of goods to rise. Meanwhile, according to the Statistics Indonesia, inflation generally means that the price of a product or service rises in which the product or service is a fundamental need of the community, or that the selling power of a national currency declines. Inflation is a continuous increase in the price of goods and services. Inflation also means that the value of money is reduced compared to the cost of general goods and services. This can be seen from the value of the Consumer Price Index (CPI). CPI is an indicator of changes in the average price of goods or services consumed by a household over a period of time [1].

Having a set of data representing the percentage of inflation rate, we can construct a function whose plot exactly passes through the data by using interpolation. Such methods include Newton Divided Difference interpolation Lagrange, Newton-Gregory interpolation and Cubic Spline. Newton-Gregory interpolation is used for data which are evenly spaced. Whereas the other methods are applied for evenly or not evenly spaced data points. Forward Gregory is used to solve problems where the destination is near the start or endpoint, and this method is used at the same intervals [2]. All the methods produce smooth interpolation functions including Cubic Spline [3].

The cubic spline is formed with the property that the function or formula and its first and second derivatives are continous at their common point between two adjacent subintervals, hence they do thorough the whole interval [4]. With this property Cubic Spline can well approximate the pattern of data. All these interpolation methods can be used to find out the percentage of the inflation rate in West Java.

Several studies used Newton-Gregory Forward Interpolation and Cubic Spline Interpolation. Gupta, *et al*., discussed the prediction of crop using Newton's interpolation (backward and forward) to get optimal crop prices [5]. Ibrahim, *et al*., conducted researched on data management and sensor energy conservation with on-node and in-node data processing mechanisms (between nodes) with the Newton forward difference method to reduce the amount of data generated at each sensor node.

The results is obtained if the Newton forward difference method can help the Wireless Sensor Network (WSN) to manage data more simply [6]. Hong, *et al*., discussed the approach of the Cubic-spline interpolation (CSI) scheme for digital image processing by combining the least-squares method. The obtained approximation results are superior compared to other interpolation functions with a value of about 0.2d-B and save about 4% compared to the direct computational CSI scheme [7]. Bogdanov and Volkov, discussed several studies on cubic splines to describe cases with conditions formulated as the first derivative with similar results for the second derivative and also a mathematical solution to obtain sufficient conditions for interpolation. The development of a cubic spline obtained general conditions for the spline and its derivatives in the form of a positive function [8].

As having evenly spaced of data, interpolation on the total annual inflation rate percentage in West Java will be carried out using Newton-Gregory Forward Interpolation method. However as a comparison, Cubic Spline will also be applied to the data. With this research, we expect to obtain better interpolation method between the two methods for prediction on the percentage of the annual inflation rate in West Java.

2. MATERIALS AND METHODS

2. 1. Materials

The data used in this study is the percentage of inflation from 2008-2020 obtained from the Statistics Indonesia as shown in Table 1. The variables include year as an independent variable (x) and annual inflation percentage as a dependent variable (y).

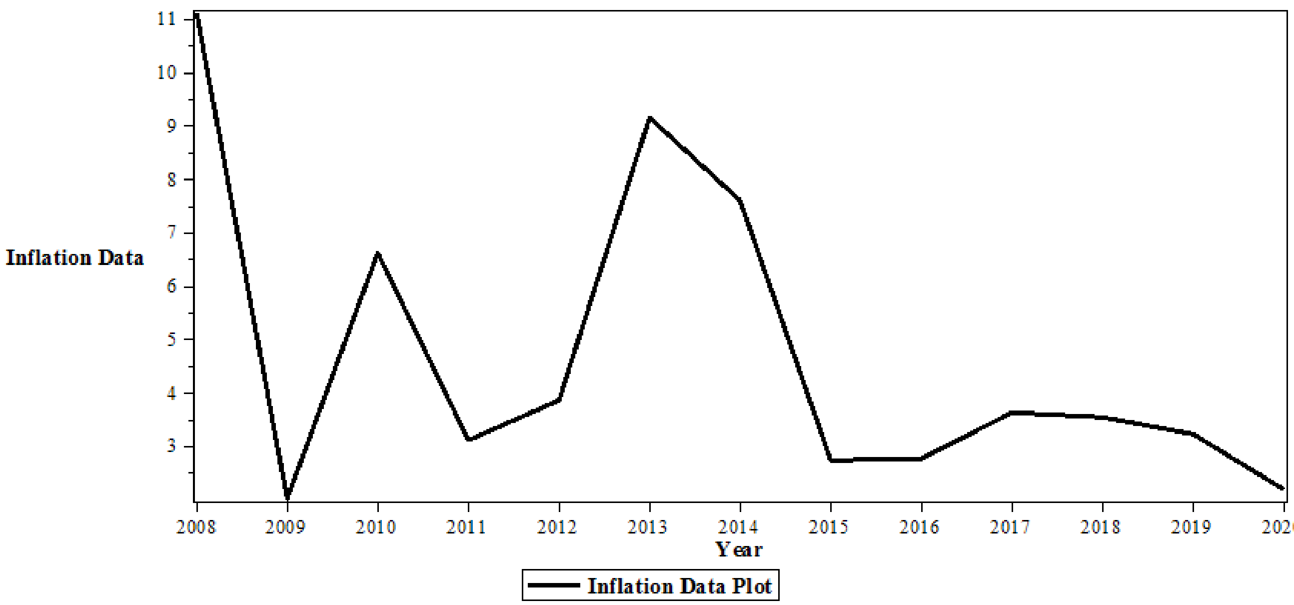

Figure 1. Plot of Inflation Data in West Java

Table 1. Inflation Data in West Java

n	Year	Inflation Percentage
0	2008	11.11
1	2009	2.02
2	2010	6.62
3	2011	3.1
4	2012	3.86
5	2013	9.15
6	2014	7.6

7	2015	2.73
8	2016	2.75
9	2017	3.63
n	Year	Inflation Percentage
10	2018	3.54
11	2019	3.21
12	2020	2.18

2. 2. Methods

2. 2. 1. Interpolation

Interpolation is a process of constructing/computing a function whose graph passes through a given number of points [9]. Interpolation is a numeric system used to determine the value of a function of an independent variable or data point outside the interpolation point but still lies within the interval. Interpolation can be applied to various fields, including statistics, applied mathematics, economics, and business problems [10].

Interpolation is commonly used to solve the problem of approximating a function with a simpler one by interpolating at discrete points, such as in differential or integral problems. Differentiating or integrating a function numerically can be done by replacing the function with a simpler approximation obtained by interpolation. Thus, interpolation is widely used in computer graphics to obtain curves with smooth surfaces on separate sets of data points [11].

2. 2. 2. Newton-Gregory forward interpolation method

The Newton-Gregory polynomial interpolation method is a polynomial interpolation reconstructed from the Taylor series and is commonly used to perform numerical calculations on derived values [12]. Forward difference denoted by lambda (Δ) is an expression of identity difference which gives an interpolated value where the value lies between the point f_n with the first value being f_0 [13]. Newton-Gregory Forward Polynomial Interpolation has equidistant interpolation points, and can be solved using the following equation:

$$P_n(x) \approx f_0 + \frac{s}{1!}\Delta f_0 + \frac{s(s-1)}{2!}\Delta^2 f_0 + \cdots + \frac{s(s-1)(s-2)\ldots(s-n+1)}{n!}\Delta^n f_0 \quad \ldots(1)$$

where:

$$\Delta f_0 = f_1 - f_0\,,\ \Delta^2 f_0 = \Delta f_1 - \Delta f_0,\ \Delta^n f_0 = \Delta^{n-1} f_1 - \Delta^{n-1} f_0$$

$$h = x_{i+1} - x_i,\ s = \frac{x - x_0}{h}$$

2. 2. 3. Cubic spline interpolation method

The cubic spline interpolation function is a set of cubic polynomials with second derivatives that are continuous throughout their intervals [14]. Cubic spline interpolation is used to form a smooth curve through a series of point shapes. Take $(n+1)$ distinct points on the interval satisfying $[a, b]$: [4]

$$a = x_0 < x_1 < \cdots < x_n = b$$

From the above conditions, each subinterval between a and b is subjected to interpolation so that it has N different cubic functions. Cubic functions are denoted by $s_i(x)$ corresponding to the intervals to be identified. $s_i(x)$ is written as [15]

$$s_i(x) = c_{0,i} + c_{1,i}(x - x_i) + c_{2,i}(x - x_i)^2 + c_{3,i}(x - x_i)^3 \quad i = 1,2, \dots, n \qquad \dots(2)$$

where: the four $c_{k,i}$ coefficients with $k = 0,1,2,3$ are unknown.

3. RESULTS AND DISCUSSION

3. 1. Newton-Gregory forward interpolation method

The first step taken is to determine the forward difference table based on inflation data in West Java.

Table 2. Forward Difference Table.

n	x	$f(x)$	Δf	$\Delta^2 f$	$\Delta^3 f$	$\Delta^4 f$	$\Delta^5 f$	$\Delta^6 f$	$\Delta^7 f$	$\Delta^8 f$	$\Delta^9 f$	$\Delta^{10} f$	$\Delta^{11} f$	$\Delta^{12} f$
0	2008	11.11	-9.09	13.69	-21.81	34.21	-46.36	46.89	-20.91	-41.78	134.45	-219	211.88	25.88
1	2009	2.02	4.6	-8.12	12.4	-12.15	0.53	25.98	-62.69	92.67	-84.55	-7.12	237.76	
2	2010	6.62	-3.52	4.28	0.25	-11.62	26.51	-36.71	29.98	8.12	-91.67	230.64		
3	2011	3.1	0.76	4.53	-11.37	14.89	-10.2	-6.73	38.1	-83.55	138.97			
4	2012	3.86	5.29	-6.84	3.52	4.69	-16.93	31.37	-45.45	55.42				
5	2013	9.15	-1.55	-3.32	8.21	-12.24	14.44	-14.08	9.97					
6	2014	7.6	-4.87	4.89	-4.03	2.2	0.36	-4.11						
7	2015	2.73	0.02	0.86	-1.83	2.56	-3.75							
8	2016	2.75	0.88	-0.97	0.73	-1.19								

9	2017	3.63	-0.09	-0.24	-0.46									
n	x	$f(x)$	Δf	$\Delta^2 f$	$\Delta^3 f$	$\Delta^4 f$	$\Delta^5 f$	$\Delta^6 f$	$\Delta^7 f$	$\Delta^8 f$	$\Delta^9 f$	$\Delta^{10} f$	$\Delta^{11} f$	$\Delta^{12} f$
10	2018	3.54	-0.33	-0.7										
11	2019	3.21	-1.03											
12	2020	2.18												

As having 13 distinct points, the degrees of polynomial of the method are at most 12. By referring to equation (1) and writing in the form of nested multiplication, the following equation is obtained

$$\begin{aligned} P_{12}(x) \approx\ & 11.11 + (x-2008)(-9.09 + (x-2009)(6.845 \\ & +(x-2010)(-3.635 + (x-2011)(1.425417 \\ & +(x-2012)(-0.38633 + (x-2013)(0.065125 \\ & +(x-2014)(-0.00415 + (x-2015)(-0.00104 \\ & +(x-2016)(0.000371 + (x-2017)(-0.0000603505 \\ & +(x-2018)(0.0000053080407 + (x-2019) \\ & \ (0.000000054029))))))))))) \end{aligned} \qquad \ldots(3)$$

Equation (3) is then plotted giving a graph as shown in Figure 2 that follows,

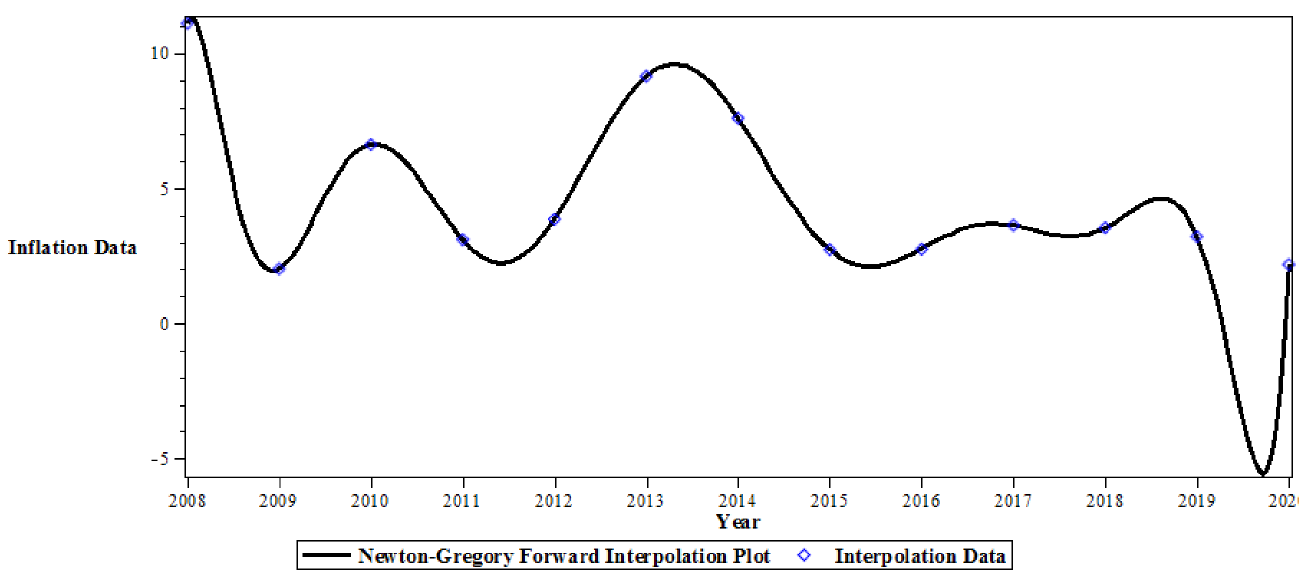

Figure 2. Newton-Gregory Forward Interpolation Plot

The results of the interpolation (3) is then used to find midpoint data as shown in Table 3 and Figure 3 that follows,

Table 3. Results of Newton-Gregory Forward Interpolation at the midpoint of Inflation data in West Java

No	x	Interpolation Results
1	2008.5	5.15
2	2009.5	4.71
3	2010.5	5.44
4	2011.5	2.26
5	2012.5	6.82
No	x	Interpolation Results
6	2013.5	9.43
7	2014.5	4.85
8	2015.5	2.12
9	2016.5	3.54
10	2017.5	3.26
11	2018.5	4.55
12	2019.5	-3.58

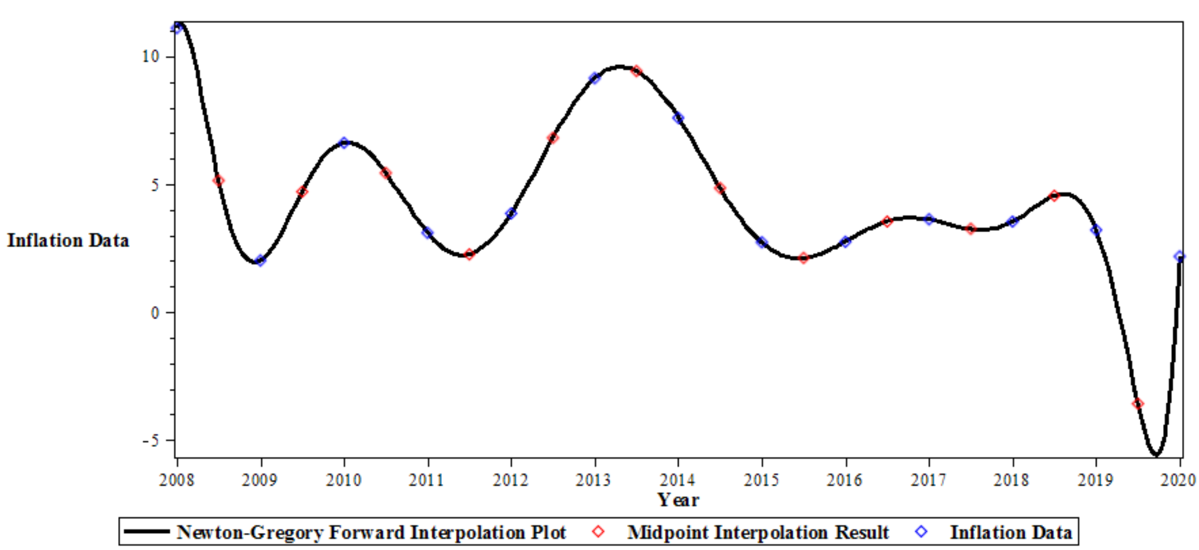

Figure 3. Newton-Gregory Forward Interpolation Plot of Midpoint Inflation Result

On the picture above, the interpolation points (Table 1) are colored in blue, while the midpoint data are colored in red. It can be seen, although the method results in a smooth function, but there are still large errors and the dynamics of the most significant change in the values of the function occurs in the [2018,2019] and [2019,2020] subintervals. Therefore, estimates of data which belong to those subintervals will certainly contain large errors. This motivates discussion of the following method to obtain better estimates of the data.

3. 2. Cubic spline interpolation method

By using Maple 18 software, the function obtained using the cubic spline interpolation method is as follows:

$$f(x) = \begin{cases} s_0(x), & \text{for } 2008 \leq x < 2009 \\ s_1(x), & \text{for } 2009 \leq x < 2010 \\ s_2(x), & \text{for } 2010 \leq x < 2011 \\ s_3(x), & \text{for } 2011 \leq x < 2012 \\ s_4(x), & \text{for } 2012 \leq x < 2013 \\ s_5(x), & \text{for } 2013 \leq x < 2014 \\ s_6(x), & \text{for } 2014 \leq x < 2015 \\ s_7(x), & \text{for } 2015 \leq x < 2016 \\ s_8(x), & \text{for } 2016 \leq x < 2017 \\ s_9(x), & \text{for } 2017 \leq x < 2018 \\ s_{10}(x), & \text{for } 2018 \leq x < 2019 \\ s_{11}(x), & \text{for } 2019 \leq x < 2020 \end{cases} \quad \ldots(4)$$

where: spline functions $s_i(x)$ for $i = 0, \ldots, 11$ are given as follows

$$\begin{aligned}
s_0(x) &= 26903.13 - 13.39x + 4.30(x-2008)^3 \\
s_1(x) &= 976.64 - 0.49x + 12.91(x-2009)^2 - 7.82(x-2009)^3 \\
s_2(x) &= -3737.88 + 1.86x - 10.56(x-2010)^2 + 5.18(x-2010)^3 \\
s_3(x) &= 7497.33 - 3.73x + 4.97(x-2011)^2 - 0.48(x-2011)^3 \\
s_4(x) &= -9580 + 4.76x + 3.52(x-2012)^2 - 2.99(x-2012)^2 \\
s_5(x) &= -5672.45 + 2.82x - 5.46(x-2013)^2 + 1.09(x-2013)^3 \\
s_6(x) &= 9741.97 - 4.83x - 2.19(x-2014)^2 + 2.16(x-2014)^3 \\
s_7(x) &= 5542.05 - 2.75x + 4.28(x-2015)^2 - 1.51(x-2015)^3 \\
s_8(x) &= -2576.77 + 1.28x - 0.25(x-2016)^2 - 0.15(x-2016)^3 \\
s_9(x) &= -663.90 + 0.33x - 0.67(x-2017)^2 + 0.28(x-2017)^3 \\
s_{10}(x) &= 474.41 - 0.23x + 0.13(x-2018)^2 - 0.23(x-2018)^3 \\
s_{11}(x) &= 1330.94 - 0.66x - 0.56(x-2019)^2 + 0.186(x-2019)^3 \qquad (5)
\end{aligned}$$

Some properties owned by Cubic Spline, such as continuities of the spline function (5) and their first and second derivatives, make them to have small errors through the interval. This can be seen in Figure 4 as follows,

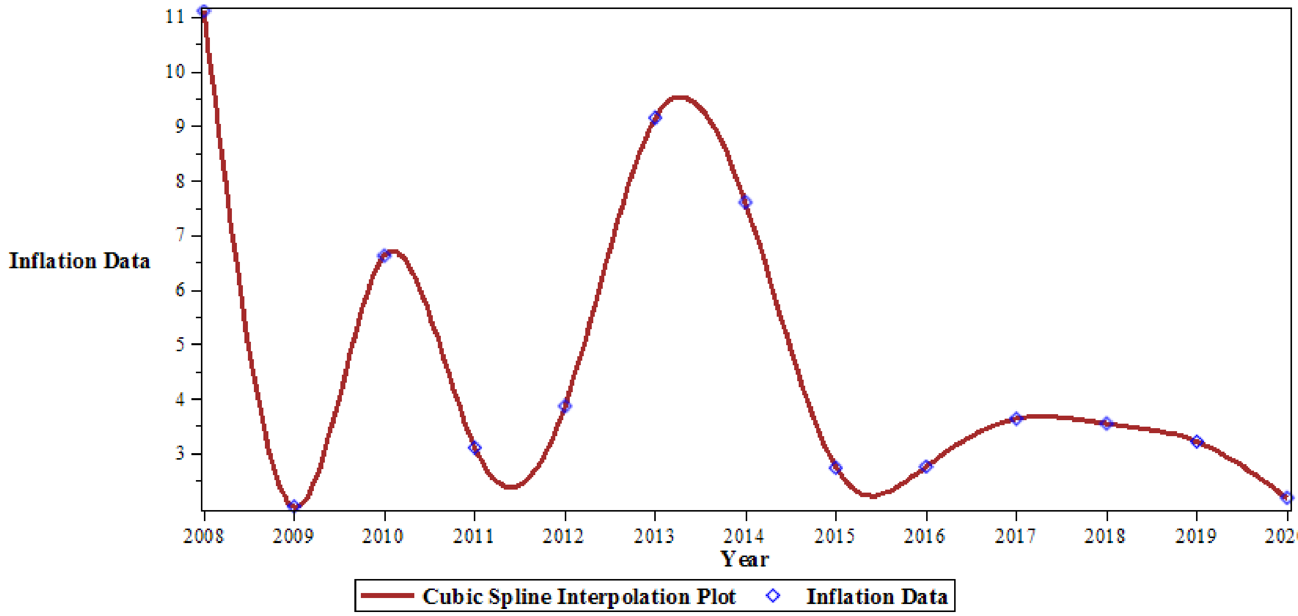

Figure 4. Cubic Spline Interpolation Plot

Cubic Spline (5) is then used to obtain the estimates of midpoint data shown in Table 4 as follows,

Table 4. Estimates of midpoint data using Cubic Spline

No	Year (x)	Interpolation Results
1	2008.5	4.95
2	2009.5	4.03
3	2010.5	5.56
4	2011.5	2.42
5	2012.5	6.75
6	2013.5	9.33
7	2014.5	4.90
8	2015.5	2.24
9	2016.5	3.31
10	2017.5	3.66

11	2018.5	3.43
12	2019.5	2.76

We then add the midpoint data to the plot of Cubic Spline (Figure 4) shown in Figure 5 that follows,

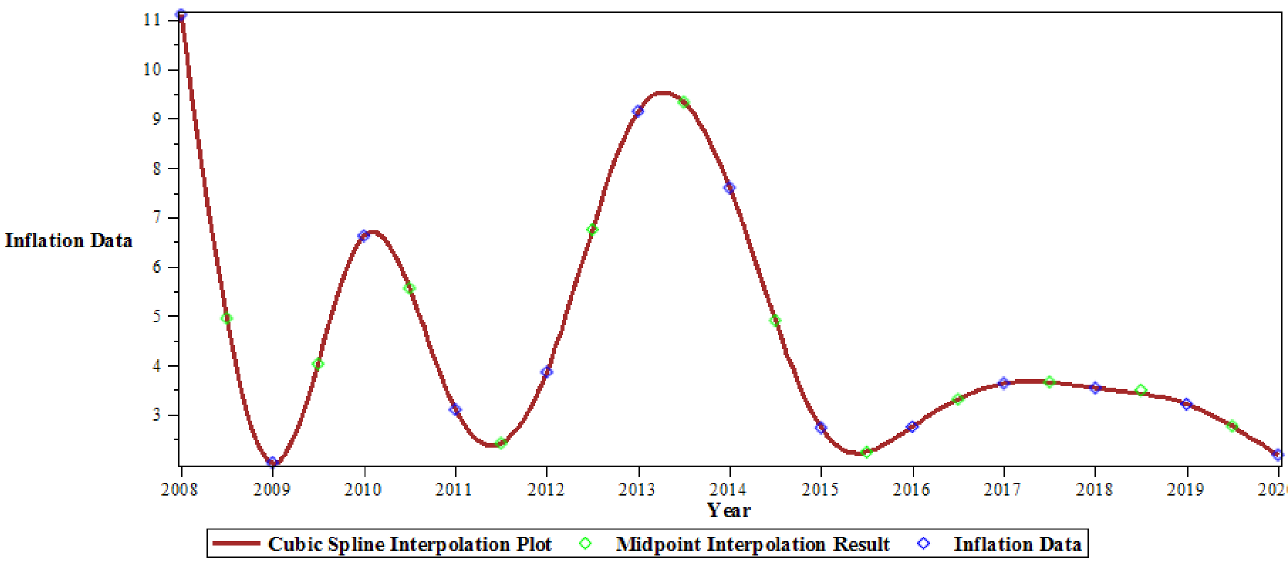

Figure 5. Plot of Cubic Spline along with interpolation and midpoint data

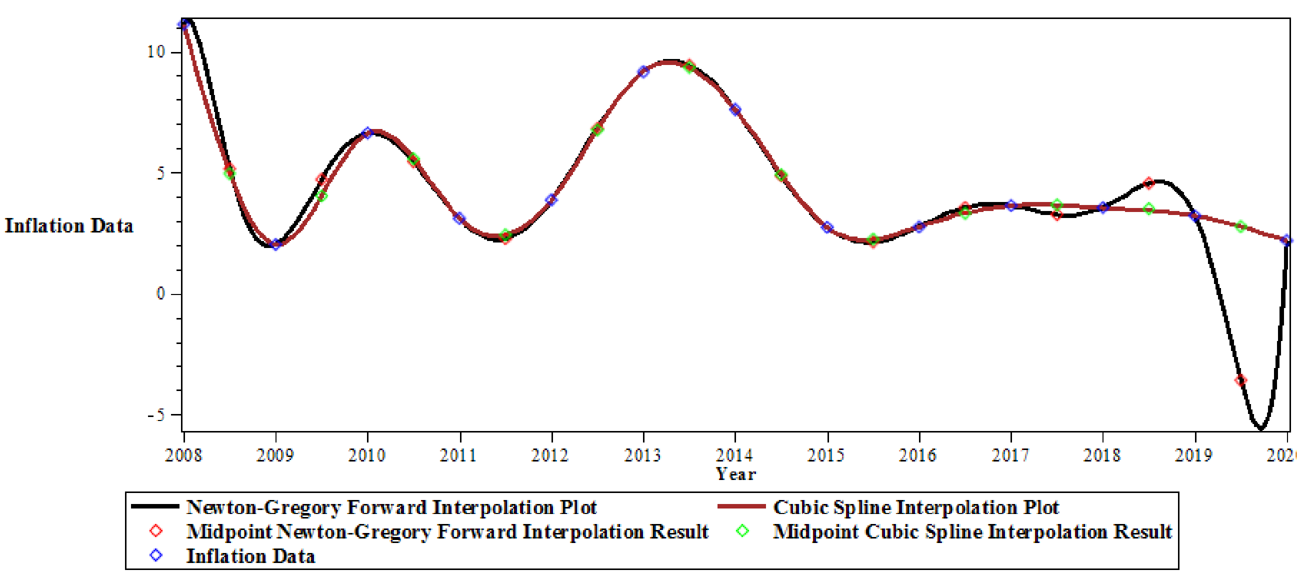

Figure 6. Comparison Plot of Newton-Gregory Forward Interpolation and Cubic Spline Interpolation

In Figure 5 the interpolation points (Table 1) are colored in blue, while midpoint data are colored in green. It can be seen that Cubic Splines fits the data extremely well. This due to Cubic Spline that produces small errors thorough the interval and has no significant changes in its values over the interval. This is distributed by the fact that the spline functions, as well as their first and second derivatives, are continues over their corresponding subinterval. Both methods are then compared to find out which one better fits the data, by plotting them together shown in Figure 6 that follows,

Figure 6 shows that both methods produce smooth functions without corners thorough the interval. However, Cubic Spline strictly fits the data being similar to the one shown in Figure 1. Whereas, Newton-Gregory interpolation shows significant changes in its values, especially within subintervals [2018,2019] and [2019,2020].

4. CONCLUSION

Based on the results of research to predict the pattern or function of inflation data in West Java using Newton-Gregory Forward Interpolation and Cubic Spline Interpolation, the plots of the two methods are precisely through the interpolation points and both methods produce a smooth function. A more specific result for comparison of the two methods can be seen from the dynamics of changes in the values of the function in each method. In the plot of Newton-Gregory Forward Interpolation, the dynamics of the most significant change in the value of function occurs near the right end of interval, especially within subintervals [2018,2019] and [2019,2020]. This is due to the higher the degree of Newton-Gregory Forward Interpolation, the larger the errors of the function near the ends of interval. On the other hand, Cubic Spline does not have errors greatly changing thorough interval. Therefore, it can be concluded that Cubic Spline Interpolation produces a better prediction of the pattern or function of inflation data in West Java than the other one produces. This hence implies that cubic spline can appropriately predict data other than the given set of data.

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