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Gold Price Fluctuation Forecasting Based on Newton and Lagrange Polynomial Interpolation

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Abstract

Gold is a highly valuable commodity and an investment opportunity for many people. However, there are often significant fluctuations in gold prices that affect investment decisions. Various mathematical forecasting methods have been developed to anticipate gold price fluctuations. This study uses historical daily data of gold prices during January-May 2023. The method used in this study is the Newton and Lagrange polynomial interpolation method with several orders to analyze data and forecast gold price fluctuations. The purpose of this study is to compare the performance and accuracy of the order levels of the Newton and Lagrange polynomial interpolation forecasting models. In this study, the test data points and orders are selected so that a range is formed that matches the amount of data available. The test orders used in this study include orders 2, 3, 5, 6, and 10. This study found that the 2^{nd} order polynomial interpolation method is more effective and accurate in forecasting gold price fluctuations compared to the higher orders tested. This is indicated by the results of the calculation of MAE, RMSE, and MAPE values in 2^{nd} order polynomial interpolation which are smaller than in 3^{rd}, 5^{th}, 6^{th}, and 10^{th} order polynomial interpolation. This suggests that a polynomial of 2^{nd} order has been able to model and forecast gold price fluctuations well. However, it is important to remember that these conclusions are based on the data and methods used in this study. Variability in forecasting results can occur depending on the quality of the data, the time period used, and the interpolation method applied, among others. Therefore, further research and wider testing needs to be conducted to validate these conclusions.

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A. INTRODUCTION

Gold is one of the most popular investment instruments in the world, due to its stable value and ability to last for long periods of time. However, gold prices often experience significant fluctuations, which can affect investor's investment decisions (Radhamani et al. (2022); Tripurana et al. (2022); Haris (2020)). The gold price is the market price of the precious metal gold, which is often used as an investment tool and a reserve of value (Haris (2020)). Gold price fluctuations are price changes that occur in a certain period of time, which can be influenced by various factors. One of the influencing factors is the monetary policy of the central bank, such as interest rates and inflation (ul Sami & Junero (2017)). When interest rates and inflation are low, the value of the currency becomes stronger and gold prices tend to decrease, and vice versa. Another influencing factor is market demand and supply. If the market demand for gold increases, the price tends to rise due to the limited supply of gold, and vice versa. In addition, geopolitical and security factors can also affect gold price fluctuations (Nugroho (2018); Rakhmawati & Nurhalim (2021)). Political or security crises can cause global uncertainty and tension, thereby increasing market demand for gold as a reserve of value.

Gold price fluctuations can affect investment and trading decisions in global financial markets (Sravani et al. (2021)). Therefore, forecasting gold price fluctuations is important to make the right investment decisions and minimize the risk of loss (Hendrian et al. (2021)). To help forecast gold price fluctuations, various math-based forecasting methods have been developed. Among the widely used methods are Newton and Lagrange polynomial interpolation. These methods produce polynomials that are capable of interpolating historical gold price data, so they can be used to forecast gold prices. Although Newton and Lagrange polynomial interpolation has been used in many forecasting applications, there are still some problems that need to be addressed. One of them is forecasting accuracy which can be affected by many factors, such as the amount of test data used and sudden changes in economic or political factors that affect gold prices.

Research into the forecasting of gold price fluctuations based on Newton and Lagrange polynomial interpolation can help improve understanding of the method and find ways to improve forecasting accuracy. Through this research, it is also expected to find a more accurate and effective gold price forecasting model. The model is expected to benefit investors and traders in making better investment decisions in the face of unpredictable gold price fluctuations and minimize the risk of loss. In addition, this research can also open up opportunities for the development of other forecasting methods using different mathematical methods.

Newton and Lagrange polynomial interpolation are two methods used to estimate the value at a point not contained in the data set, based on known data points (Astuti et al. (2018)). The Newton polynomial interpolation method uses a low-order polynomial and a dividend difference table. The dividend difference table is constructed from known data points, which are then used to construct the interpolating polynomials (Muhammad (2011)). The process of creating a dividend difference table involves calculating the differences from known data points (Astuti et al. (2018)). Meanwhile, the Lagrange polynomial interpolation method uses higher-order polynomials and does not require a dividend difference table (Pratama et al. (2014)). This method is based on creating interpolation polynomials using Lagrange basis functions, which are constructed from known data points. Each data point is associated with a basis function associated with it, and then interpolation polynomials are constructed from these basis functions.

There have been many previous studies that forecasted gold prices using various methods. Among these studies are articles that discuss the forecasting of gold prices using the ARIMA model and the ARIMA time series approach (Anggraeni et al. (2020); Sunyanti. & Mukhaiyar (2019)); deterministic trend model (Rakhmawati & Nurhalim (2021)); double exponential smoothing model with LOCF imputation and linear interpolation (Siregar et al. (2021)). These studies developed a model to forecast the global gold price throughout the COVID-19 pandemic, solely relying on historical gold price data and excluding any external factors that could impact the model. Meanwhile, there are articles that discuss machine learning algorithms, approaches, and techniques (Pragna et al. (2022); Radhamani et al. (2022); ul Sami & Junero (2017); Tripurana et al. (2022)) that applied machine learning technique to forecast financial financial indicators, with a primary focus on forecasting the price of gold. In another research, discuss the forecasting of gold prices using Generalized Autoregressive Conditional Heteroscedasticity (Garch) model (Haris (2020)); local polynomial nonparametric method equipped with GUI R (Hendrian et al. (2021)); average-based fuzzy time series method (Hariwijaya et al. (2020)); multiple linear regression method (Sravani et al. (2021)); Nearest Neighbor Retrieval method (Nugroho (2018)); data mining techniques (Mahena et al. (2015)). These research explores gold price forecasting in the context of making investment decisions in gold stocks. It presents the outcomes of a forecasting process capable of creating models and predictions using historical data. Additionally, there is an article that conducts a comparison between Naive Bayes, support vector machine, and K-NN methods for forecasting fluctuations in gold prices, specifically within the realm of gold stock investment (Suryana & Sen (2021)).

On the other hand, there are also several previous studies that discuss the application of polynomial interpolation methods to forecast various data. There is article that discuss the application of the polynomial interpolation method to forecast the population of the province of East Nusa Tenggara by applying the Lagrange Interpolation method that found every year the population increases (Hurit & Nanga (2022); Pratiwi et al. (2017)). In another research, discuss the forecasting of virus spread in all regions of Indonesia using Newton Raphson interpolation method (Aulia et al. (2020)). Meanwhile, there are articles that discuss the forecasting of stock prices using several polynomial interpolation methods such as Newton-Gregory forward, Newton-Gregory backward, Newton, and Lagrange (Muhammad (2011); Pangruruk & Barus (2016, 2018a); Pangruruk et al. (2020); Pangruruk & Barus (2018b)). Additionally, there is an article that forecasting of the number of elementary, junior high, high school, and vocational school students in NTB Province, using the Newton-Gregory Advanced Polynomial method (Negara et al. (2020)). Furthermore, there are studies that discuss the relationship between land area and palm oil production to forecast the agricultural production (palm oil production) in Riau province using Newton-Gregory forward polinomial interpolation (Sihombing (2019)).

Although polynomial interpolation has long been discovered and widely used in various fields, research that discusses its application in forecasting gold price fluctuations is still relatively new and has not been done in previous studies. Moreover, the novelty of this research is that it combines research that applies polynomial interpolation (Newton and Lagrange) and research that uses gold price data. In addition, this research uses the latest (data in 2023) and comprehensive (daily price data) gold price data information to improve forecasting accuracy. This study also compares the performance and accuracy of the order level of the polynomial interpolation forecasting model (Newton and Lagrange). The purpose of this study is to apply the Newton and Lagrange polynomial interpolation methods to historical gold price data to create a mathematical model that can predict gold price fluctuations, compare the performance and accuracy of the order levels of the Newton and Lagrange polynomial interpolation forecasting models, and present the results of gold price forecasts visually in the form of curves to facilitate interpretation and decision making.

B. RESEARCH METHOD

The research method used in this study is as follows:

1. Determining the data points to be studied.

At this stage, matching points in a cartesian coordinate over a finite set of pairs of points $(x_0, y_0), (x_1, y_2), \ldots, (x_n, y_n)$ without knowing the shape of the function rule. In this study, historical data points of daily gold prices during January-May 2023 were selected, namely 151 data points. The data was collected from the official web source of gold prices in Indonesia (www.logammulia.com). The selection of these data points is based on the consideration that these data are the latest and relevant data in forecasting gold prices.

2. Determine the form of the Newton and Lagrange polynomial interpolation equation.

The historical data points that have been obtained are then processed and analyzed using Scilab 2023.1.0 software with Newton and Lagrange polynomial interpolation techniques. Based on the historical data points, test data points and test orders are then selected so that a range is formed that matches the amount of historical data available. At this stage, Newton and Lagrange polynomial interpolation techniques of order 2, 3, 5, 6, and 10 are used to build a mathematical model that can be used to forecast gold prices. The polynomial interpolation technique is a mathematical technique used to estimate the value of the function $f(x)$ at points between known data points (Astuti et al. (2018)).

The form of the polynomial interpolation equation can be determined using the general equation of a polynomial of a certain degree. In the Newton polynomial interpolation method, the form of the n-degree polynomial interpolation equation for $(n+1)$ data points is as follows (Astuti et al. (2018)):

$$p_n(x) = a_0 + a_1(x-x_0) + a_2(x-x_0)(x-x_1) + \ldots + a_n(x-x_0)(x-x_1)\ldots(x-x_{n-1}) \tag{1}$$

For the Newton polynomial interpolation method in this study, the polynomial coefficients are determined using the forward difference technique (Astuti et al. (2018)). The forward difference technique is used because the data has the same distance between points, which is data at the same time period. The equations used to calculate the coefficients of the Newton polynomial are:

- $a_0 = y_0 = f(x_0)$
- $a_1 = \frac{y_1 - y_0}{x_1 - x_0} = f[x_1, x_0]$
- $a_2 = \frac{f[x_2,x_1] - f[x_1,x_0]}{x_2 - x_0} = f[x_2, x_1, x_0]$

  $\vdots$
- $a_n = \frac{f[x_n,x_{n-1},\ldots,x_2,x_1] - f[x_{n-1},x_{n-2},\ldots x_1,x_0]}{x - x_0} = f[x_n, x_{n-1}, \ldots, x_1, x_0]$

The square bracketed function value is called the divided difference value, so the coefficients a_i are also called Newton divided difference coefficients. The coefficients of the polynomial can be determined using a forward difference table, known as its dividend difference table. This table is organized by the finite differences of the values of $f(x)$ at the data points. Each row in this table indicates a finite difference of a higher order than the previous row.

As for the Lagrange polynomial interpolation method, the form of an n-degree polynomial for $(n+1)$ data points is as follows:

$$p_n(x) = a_0L_0(x) + a_1L_1(x) + \ldots + a_nL_n(x) \tag{2}$$

For the Lagrange polynomial interpolation method, the polynomial coefficients are determined by calculating the nth Lagrange polynomial and function values at the data points. Furthermore, the equations used to calculate the coefficients on the Lagrange polynomials are:

- $a_i = y_i$
- $L_i(x) = \frac{(x-x_0)(x-x_1)\ldots(x-x_{i-1})(x-x_{i+1})\ldots(x-x_n)}{(x_i-x_0)(x_i-x_1)\ldots(x_i-x_{i-1})(x_i-x_{i+1})\ldots(x_i-x_n)}$

3. Calculate the gold price forecasting from the polynomial interpolation equation obtained.

After obtaining a polynomial equation that matches the specified order and test data, the next step is to calculate the gold price at the desired time. To calculate the price of gold at a certain time using Newton and Lagrange polynomial interpolation, the value of x in the polynomial equation is replaced with the time index you want to forecast, then the result is calculated. The result will give an estimate of the gold price at the desired time.

4. Plotting the curve.

At the stage of describing the curve, Microsoft Excel software is used to visualize the data and model forecasting results. After the mathematical model is built using Newton and Lagrange polynomial interpolation techniques, the gold price forecasting value is calculated by entering the desired time data index value as input. Then, the forecasted value is depicted in the form of a curve with the x-axis being the time period and the y-axis being the gold price. The curve is then compared between the actual data and the forecasted data to evaluate the accuracy of the model. The evaluation results are used to determine which order of polynomial interpolation is more accurate in forecasting gold prices.

5. Evaluating the accuracy of the polynomial interpolation model.

After forecasting gold prices using the polynomial interpolation method, the next step is to evaluate the accuracy of the model. In this research, evaluating the accuracy of the model is done by comparing the forecasted data with the actual data available. The methods used to evaluate model accuracy include the Mean Absolute Error (MAE), Root Mean Squared Error (RMSE) and Mean Absolute Percentage Error (MAPE) methods. MAE, RMSE, and MAPE are measures of forecasting error used to measure how far the forecasting results are from the actual value. The smaller the MAE, RMSE, and MAPE values, the more accurate the polynomial interpolation forecasting model used (Lamabelawa (2019); Muhammad Julian et al. (2022)). The following are the formulas given for MAE, RMSE, and MAPE:

- $MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i|$;
- $RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}$;
- $MAPE = \frac{1}{n}\sum_{i=1}^{n}|\frac{y_i - \hat{y}_i}{y_i}| \times 100\%$

Description:
y_i is the actual value of the i^{th} observation,
$\hat{y}_i$ is the forecasted value of the i^{th} observation,
n is the total number of observations in the sample.

6. Interpreting the results.

After performing steps 1-5, the results will be obtained in the form of gold price forecasting based on existing historical data. The forecasting results should be interpreted with caution and should not be taken as certainty. Therefore, it is necessary to evaluate the forecasting results obtained, such as by comparing the forecasting results with actual data. If the forecasting results have a large error, it is necessary to review the historical data and the polynomial interpolation method used. This aims to ensure that the forecasting obtained are more accurate and can be used as a guide in providing recommendations and advice to investors and traders on how to use the mathematical model that has been developed for planning and in making better investment decisions in the face of unpredictable gold price fluctuations and minimizing the risk of loss. In addition, it should be noted that the forecasting results obtained through the Newton and Lagrange polynomial interpolation method are predictive and derived from historical data. Therefore, they cannot take into account external factors that may affect gold prices, such as changes in monetary policy from central banks, market supply and demand, or geopolitical and security factors. Therefore, it is necessary to periodically review and evaluate the forecasting results obtained to ensure that they are in line with actual conditions.

C. RESULT AND DISCUSSION

Based on 151 historical data points of daily gold prices during January-May 2023 taken from the official website of gold prices in Indonesia (www.logammulia.com), the points are matched in a cartesian coordinate, namely $(x_0, y_0), (x_1, y_1), \ldots, (x_{150}, y_{150})$. From these historical data points, the following points were selected as test data points presented in Table 1.

Table 1. Daily Gold Price Test Data Point

Date	x_i	y_i	Date	x_i	y_i	Date	x_i	y_i	Date	x_i	y_i
01/01/2023	0	1026	10/02/2023	40	1026	22/03/2023	80	1074	01/05/2023	120	1054
06/01/2023	5	1022	15/02/2023	45	1029	27/03/2023	85	1087	06/05/2023	125	1059
11/01/2023	10	1035	20/02/2023	50	1020	01/04/2023	90	1072	11/05/2023	130	1072
16/01/2023	15	1042	25/02/2023	55	1012	06/04/2023	95	1078	16/05/2023	135	1064
21/01/2023	20	1035	02/03/2023	60	1024	11/04/2023	100	1069	21/05/2023	140	1056
26/01/2023	25	1025	07/03/2023	65	1032	16/04/2023	105	1067	26/05/2023	145	1043
31/01/2023	30	1027	12/03/2023	70	1049	21/04/2023	110	1054	31/05/2023	150	1056
05/02/2023	35	1014	17/03/2023	75	1063	26/04/2023	115	1062			

Furthermore, the Newton and Lagrange polynomial interpolation method is used to build the forecasting model. In Figure 1, the Scilab software script for Newton and Lagrange polynomial interpolation is presented in general.

newton.sci

```
function [P]=newton(X,Y) //X nodes,Y values;
P is the numerical Newton polynomial interpolation
n=length(X); // n is the number of nodes. (n-1) is the degree
for j=2:n,
for i=1:n-j+1,Y(i,j)=(Y(i+1,j-1)-Y(i,j-1))/(X(i+j-1)-X(i)); end,
end,
x=poly(0,"x");
P=Y(1,n);
for i=2:n, P=P*(x-X(i))+Y(i,n-i+1); end,
endfunction
```

(a)

lagrange.sci

```
function [P]=lagrange(X,Y) //X nodes,Y values;
P is the numerical Lagrange polynomial interpolation
n=length(X); // n is the number of nodes. (n-1) is the degree
x=poly(0,"x");P=0;
for i=1:n, L=1;
for j=[1:i-1,i+1:n] L=L*(x-X(j))/(X(i)-X(j)); end,
P=P+L*Y(i); end,
endfunction
```

(b)

Figure 1. Scilab Function for (a) Newton Polynomial Interpolation; (b) Lagrange Polynomial Interpolation

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The following is an example for the 2^{nd} order Newton and Lagrange polynomial interpolation results for the test data $(x_0, y_0), (x_5, y_5), (x_{10}, y_{10})$ presented in Figure 2.

```
--> X=[0;5;10];

--> Y=[1026;1022;1035];

--> L=lagrange(X,Y)
 L  =

  1026 -2.5x +0.34x^2

--> N=newton(X,Y)
 N  =

  1026 -2.5x +0.34x^2
```

Figure 2. Example of 2^{nd} Order Polynomial Interpolation Results

In Figure 2, it can be seen that the interpolation results of Newton and Lagrange polynomials are the same. This is in accordance with the theory of uniqueness of polynomial interpolation (Astuti et al. (2018)). Furthermore, the polynomial function is used to forecast the gold price data for x_1 until x_4 and x_6 until x_9 presented in Figure 3 as follows

```
--> function y=f(x);
  > y=1026-2.5*(x)+0.34*(x)^2;
  > endfunction

--> f(1:1:4)
 ans  =

   1023.84   1022.36   1021.56   1021.44

--> f(6:1:9)
 ans  =

   1023.24   1025.16   1027.76   1031.04
```

Figure 3. Gold Price Data Forecasting Results

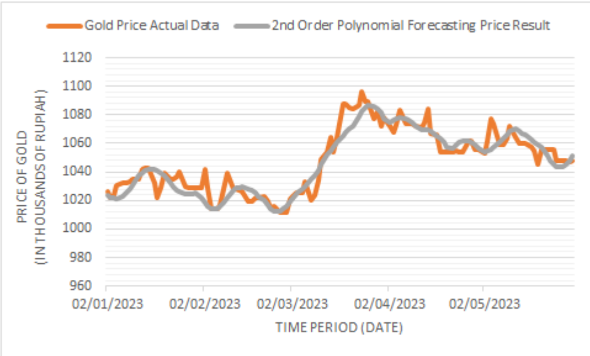
Furthermore, the following is presented in Table 2 the results of gold price forecasting calculations using Newton and Lagrange polynomial interpolation of order 2, 3, 5, 6, and 10 which have been obtained from Scilab software. Defined x value in the polynomial equation is the index of the desired time (date) variable.

Table 2. Calculation Results of Gold Price Forecasting

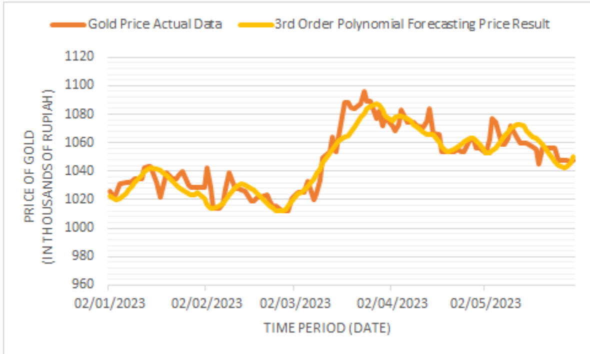
Date	x_i	y_i	$P_2(x_i)$	$P_3(x_i)$	$P_5(x_i)$	$P_6(x_i)$	$P_{10}(x_i)$
02/01/2023	1	1026	1023,84	1022,736	1022,334	1022,722	984,803
03/01/2023	2	1022	1022,36	1020,888	1020,384	1020,82	982,395
04/01/2023	3	1024	1021,56	1020,272	1019,859	1020,178	994,977
05/01/2023	4	1031	1021,44	1020,704	1020,485	1020,635	1010,008
07/01/2023	6	1032	1023,24	1023,976	1024,16	1024,063	1029,534
08/01/2023	7	1032	1025,16	1026,448	1026,737	1026,605	1033,243
09/01/2023	8	1033	1027,76	1029,232	1029,525	1029,409	1034,52
10/01/2023	9	1035	1031,04	1032,144	1032,335	1032,27	1034,763
12/01/2023	11	1035	1037,52	1037,616	1037,377	1037,434	1035,771
13/01/2023	12	1042	1039,48	1039,808	1039,347	1039,436	1037,167
14/01/2023	13	1043	1040,88	1041,392	1040,815	1040,903	1038,95
15/01/2023	14	1043	1041,72	1042,184	1041,712	1041,768	1040,708
17/01/2023	16	1032	1041,72	1041,56	1041,667	1041,603	1042,469
18/01/2023	17	1022	1040,88	1040,52	1040,733	1040,617	1041,921
19/01/2023	18	1029	1039,48	1039	1039,248	1039,115	1040,352
20/01/2023	19	1039	1037,52	1037,12	1037,298	1037,201	1037,939
22/01/2023	21	1035	1032,04	1032,76	1031,509	1032,658	1031,929
23/01/2023	22	1035	1029,56	1030,52	1030,014	1030,333	1029,125
24/01/2023	23	1037	1027,56	1028,4	1027,746	1028,182	1026,921
25/01/2023	24	1040	1026,04	1026,52	1025,971	1026,36	1025,529
27/01/2023	26	1030	1024,44	1023,96	1033,688	1024,208	1025,218
28/01/2023	27	1029	1024,36	1023,52	1036,383	1024,047	1025,916
29/01/2023	28	1029	1024,76	1023,8	1035,125	1024,519	1026,717
30/01/2023	29	1029	1025,64	1024,92	1031,565	1025,557	1027,205
01/02/2023	31	1029	1022,4	1020,768	1022,408	1019,241	1025,841
02/02/2023	32	1042	1018,8	1016,624	1018,479	1014,77	1023,661
03/02/2023	33	1029	1016,2	1014,296	1015,653	1012,828	1020,634
04/02/2023	34	1014	1014,6	1013,512	1014,149	1012,758	1017,193
06/02/2023	36	1014	1014,4	1015,488	1015,088	1016,081	1011,859
07/02/2023	37	1017	1015,8	1017,704	1017,175	1018,608	1011,581
08/02/2023	38	1028	1018,2	1020,376	1019,941	1021,262	1013,796
09/02/2023	39	1039	1021,6	1023,232	1023,013	1023,79	1018,733
11/02/2023	41	1028	1027,56	1028,408	1028,528	1027,753	1034,398
12/02/2023	42	1028	1028,64	1030,184	1030,271	1028,958	1041,845
13/02/2023	43	1027	1029,24	1031,056	1030,989	1029,568	1045,488
14/02/2023	44	1026	1029,36	1030,752	1030,557	1029,575	1042,113
16/02/2023	46	1019	1028,16	1028,032	1026,528	1027,896	1005,382
17/02/2023	47	1019	1026,84	1026,496	1023,567	1026,34	974,743
18/02/2023	48	1022	1025,04	1024,544	1020,797	1024,427	948,181
19/02/2023	49	1022	1022,76	1022,328	1019,181	1022,271	949,163
21/02/2023	51	1023	1020	1017,712	1012,822	1017,752	1015,402
22/02/2023	52	1019	1016,533	1015,616	1009,468	1015,673	1011,507
23/02/2023	53	1015	1014,044	1013,864	1008,796	1013,917	1009,719
24/02/2023	54	1016	1012,533	1012,608	1009,882	1012,639	1010,078
26/02/2023	56	1012	1012,444	1012,192	1014,601	1012,16	1014,733
27/02/2023	57	1012	1013,867	1013,336	1017,295	1013,279	1017,623
28/02/2023	58	1012	1016,267	1015,584	1019,831	1015,519	1020,229
01/03/2023	59	1021	1019,644	1019,088	1022,078	1019,04	1022,351
03/03/2023	61	1025	1024,88	1024,304	1025,644	1024,396	1025,332
04/03/2023	62	1025	1026,12	1025,352	1027,114	1025,401	1026,579
05/03/2023	63	1025	1027,72	1027,048	1028,555	1027,038	1027,985
06/03/2023	64	1033	1029,68	1029,296	1030,129	1029,266	1029,75
08/03/2023	66	1020	1034,68	1035,064	1034,311	1035,125	1034,768
09/03/2023	67	1024	1037,72	1038,392	1037,165	1038,512	1037,999
10/03/2023	68	1034	1041,12	1041,888	1040,606	1042,031	1041,567
11/03/2023	69	1049	1044,88	1045,456	1044,596	1045,562	1045,296
13/03/2023	71	1054	1052,04	1052,424	1053,562	1052,266	1052,507
14/03/2023	72	1064	1054,96	1055,632	1057,889	1055,307	1055,689
15/03/2023	73	1054	1057,76	1058,528	1061,425	1058,101	1058,481

Date	x_i	y_i	$P_2(x_i)$	$P_3(x_i)$	$P_5(x_i)$	$P_6(x_i)$	$P_{10}(x_i)$
16/03/2023	74	1064	1060,44	1061,016	1063,439	1060,654	1060,893
18/03/2023	76	1088	1065,44	1063,6	1056,758	1065,196	1064,936
19/03/2023	77	1088	1067,76	1065,24	1057,041	1067,316	1066,863
20/03/2023	78	1085	1069,96	1067,68	1061,279	1069,44	1068,944
21/03/2023	79	1084	1072,04	1070,68	1067,442	1071,647	1071,305
23/03/2023	81	1087	1078,84	1077,4	1079,86	1076,531	1076,984
24/03/2023	82	1096	1082,56	1080,64	1084,32	1079,225	1080,096
25/03/2023	83	1089	1085,16	1083,48	1087,013	1081,999	1083,059
26/03/2023	84	1089	1086,64	1085,68	1087,857	1084,685	1085,501
28/03/2023	86	1077	1086,24	1087,2	1084,77	1088,527	1087,149
29/03/2023	87	1082	1084,36	1086,04	1081,622	1088,683	1085,65
30/03/2023	88	1072	1081,36	1083,28	1078,083	1086,692	1082,41
31/03/2023	89	1078	1077,24	1078,68	1074,703	1081,552	1077,653
02/04/2023	91	1072	1074,4	1075,456	1070,409	1083,368	1066,522
03/04/2023	92	1068	1076,2	1077,608	1070,229	1086,767	1062,707
04/04/2023	93	1073	1077,4	1078,632	1071,57	1085,534	1062,315
05/04/2023	94	1083	1078	1078,704	1074,302	1082,07	1067,05
07/04/2023	96	1074	1077,4	1076,696	1081,895	1074,327	1094,747
08/04/2023	97	1074	1076,2	1074,968	1084,819	1071,563	1114,055
09/04/2023	98	1074	1074,4	1072,992	1085,152	1069,855	1128,02
10/04/2023	99	1072	1072	1070,944	1080,772	1069,092	1121,548
12/04/2023	101	1071	1069,48	1067,336	1076,782	1069,228	1090,924
13/04/2023	102	1075	1069,52	1066,128	1078,482	1069,413	1094,076
14/04/2023	103	1084	1069,12	1065,552	1076,315	1069,238	1087,458
15/04/2023	104	1067	1068,28	1065,784	1072,039	1068,472	1077,166
17/04/2023	106	1066	1065,28	1060,944	1062,174	1064,84	1059,014
18/04/2023	107	1054	1063,12	1056,912	1058,21	1062,142	1054,001
19/04/2023	108	1054	1060,52	1054,608	1055,475	1059,18	1051,909
20/04/2023	109	1054	1057,48	1053,736	1054,095	1056,322	1052,176
22/04/2023	111	1054	1056,88	1055,104	1054,966	1052,65	1056,541
23/04/2023	112	1055	1059,12	1056,752	1056,658	1052,654	1059,056
24/04/2023	113	1054	1060,72	1058,648	1058,675	1054,256	1060,99
25/04/2023	114	1054	1061,68	1060,496	1060,591	1057,475	1062,007
27/04/2023	116	1062	1061,68	1062,864	1062,558	1067,067	1061,059
28/04/2023	117	1062	1060,72	1062,792	1062,026	1071,331	1059,429
29/04/2023	118	1056	1059,12	1061,488	1060,315	1072,722	1057,457
30/04/2023	119	1056	1056,88	1058,656	1057,527	1068,283	1055,525
02/05/2023	121	1053	1054,36	1052,968	1050,35	1046,528	1053,182
03/05/2023	122	1062	1055,04	1053,184	1047,514	1045,659	1053,268
04/05/2023	123	1077	1056,04	1054,416	1046,795	1048,687	1054,328
05/05/2023	124	1074	1057,36	1056,432	1049,903	1053,608	1056,301
07/05/2023	126	1059	1060,96	1061,888	1066,745	1063,926	1062,14
08/05/2023	127	1059	1063,24	1064,864	1071,003	1067,834	1065,368
09/05/2023	128	1063	1065,84	1067,696	1072,786	1070,474	1068,31
10/05/2023	129	1072	1068,76	1070,152	1072,908	1071,82	1070,615
12/05/2023	131	1064	1070,4	1073,008	1070,534	1071,238	1072,293
13/05/2023	132	1060	1068,8	1072,944	1068,839	1069,804	1071,459
14/05/2023	133	1060	1067,2	1071,576	1067,127	1067,968	1069,61
15/05/2023	134	1060	1065,6	1068,672	1065,505	1065,971	1067,001
17/05/2023	136	1057	1062,4	1064,288	1062,578	1062,17	1061,037
18/05/2023	137	1055	1060,8	1063,384	1061,164	1060,521	1058,531
19/05/2023	138	1045	1059,2	1061,536	1059,66	1059,017	1056,808
20/05/2023	139	1056	1057,6	1058,992	1057,966	1057,558	1056,007
22/05/2023	141	1056	1051,32	1052,808	1053,719	1054,186	1056,332
23/05/2023	142	1056	1047,68	1049,664	1051,137	1051,978	1056,218
24/05/2023	143	1056	1045,08	1046,816	1048,345	1049,309	1054,626
25/05/2023	144	1048	1043,52	1044,512	1045,53	1056,235	1050,473
27/05/2023	146	1048	1043,52	1042,528	1041,196	1040,108	1032,378
28/05/2023	147	1048	1045,08	1043,344	1040,718	1038,406	1020,603
29/05/2023	148	1047	1047,68	1045,696	1042,341	1039,172	1012,779
30/05/2023	149	1048	1051,32	1049,832	1047,039	1044,22	1018,863

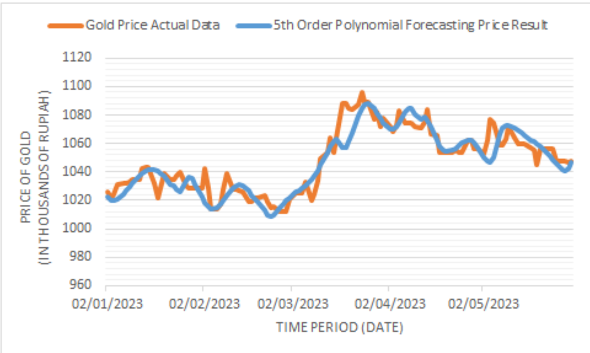
Furthermore, using Microsoft Excel software, in the Figures 4 are given respectively as comparison curves between actual data and forecasted data from the interpolation of Newton and Lagrange polynomials of order 2, 3, 5, 6, and 10. The x-axis of the curve shows the time period (Date) and the y-axis shows the price of gold (in thousands of Rupiah).



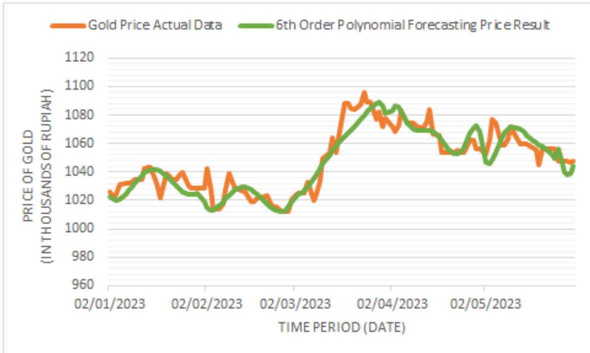
(a)



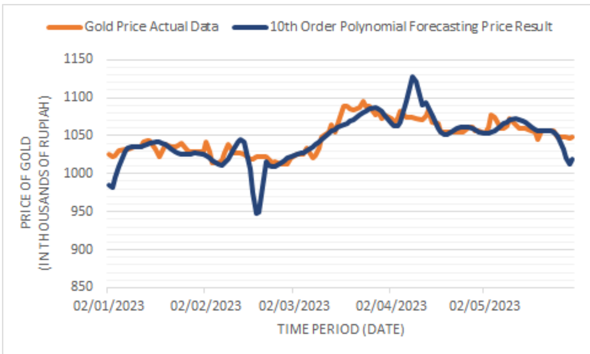
(b)



(c)



(d)



(e)

Figure 4. Comparison Curve of Actual Gold Price with Polynomial Interpolation Forecasted Price (a) 2^{nd} Order; (b) 3^{rd} Order; (c) 5^{th} Order; (d) 6^{th} Order; (e) 10^{th} Order

Furthermore, to compare the forecasting results and the actual data, the following evaluates the accuracy of the model using MAE, RMSE, and MAPE with the results as shown in Table 3.

Table 3. Results of MAE, RMSE, and MAPE

	2^{nd} Order	3^{rd} Order	5^{th} Order	6^{th} Order	10^{th} Order
RMSE	6,895	7,414	8,104	8,052	15,609
MAE	4,562	4,864	5,223	5,417	8,861
MAPE	0,434%	0,462%	0,496%	0,514%	0,846%

Based on the results in Table 3, it can be seen that the respective MAE, RMSE, and MAPE values for 2^{nd} order polynomial interpolation $< 3^{rd}$ order $< 5^{th}$ order $< 6^{th}$ order $< 10^{th}$ order. This means that the 2^{nd} order polynomial interpolation method is more effective than the 3^{rd} order polynomial interpolation method, 3^{rd} order polynomial interpolation is more effective than 5^{th} order polynomial interpolation, 5^{th} order polynomial interpolation is more effective than 6^{th} order polynomial interpolation, and 6^{th} order polynomial interpolation is more effective than 10^{th} order polynomial interpolation. From Table 3, it can also be concluded that the 2^{nd} order polynomial interpolation method is the most effective to use in forecasting gold prices because the smallest MAE, RMSE, and MAPE values are 6.895, 4.562, and 0.434% respectively. The results of this study are in line with the research of (Lamabelawa (2019); Muhammad Julian et al. (2022)). This suggests that a polynomial of 2^{nd} order has been able to model and forecast gold price fluctuations well. Furthermore, it can be said that the smaller the order of polynomial interpolation, the more effective it will be in forecasting data compared to higher order polynomial interpolation methods. However, it is important to remember that these conclusions are based on the data and methods used in this study. Variability in forecasting results can occur depending on the quality of the data, the time period used, and the interpolation method applied, among others. Therefore, further research and wider testing needs to be conducted to validate these conclusions.

D. CONCLUSION AND SUGGESTION

Based on the research that has been done, it can be concluded that the interpolation polynomial results obtained from the Newton and Lagrange methods on gold price data show similarities. This is in accordance with the interpolation polynomial uniqueness theorem. Both methods produce interpolation polynomials that can be applied to forecast gold prices. The forecasting results show a relatively small forecasting error rate based on the results of the MAE, RMSE, and MAPE values. Therefore, the application of Newton and Lagrange polynomial interpolation can be used as an alternative method in forecasting gold price fluctuations. During the research, it was found that the smaller the polynomial order used, the better the forecasting results. This is because the results showed that the MAE, RMSE, and MAPE values for polynomial interpolation of 2^{nd} order $< 3^{rd}$ order $< 5^{th}$ order $< 6^{th}$ order $< 10^{th}$ order respectively. Furthermore, in this case, it is found that the best order that gives the most effective and accurate forecasting results is 2^{nd} order. This suggests that a polynomial of 2^{nd} order has been able to model and forecast gold price fluctuations well. However, it is important to remember that these conclusions are based on the data and methods used in this study. Variability in forecasting results can occur depending on the quality of the data, the time period used, and the interpolation method applied, among others. Therefore, further research and wider testing needs to be conducted to validate these conclusions.

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