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BANK CENTRAL ASIA (BCA) WEEKLY STOCK PRICE PREDICTION BASED ON FOURIER SERIES ESTIMATOR APPROACH

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Abstract: *This study examines the Indonesian capital market, particularly Bank Central Asia (BCA) shares, as a vital investment instrument for economic growth. Fluctuations in BCA's share price are influenced by internal and external factors that often make it difficult for investors to make investment decisions. To predict BCA's stock price movements, a Fourier series estimator is used, which is effective in identifying recurring patterns in the data. With the latest data from January 2022 to November 2024, this study aims to provide an accurate prediction model, useful for investors, and assist banks in formulating long-term strategies, as well as supporting the achievement of Sustainable Development Goals (SDGs) point 8 regarding Decent Work and Economic Growth. The results showed that the Fourier series estimator produced an optimal oscillation parameter value (λ) of 17. The estimated model formed produced an MSE value of 3784.379, a MAPE value of 0.5249203%, and an R-Square value of 97.7224% which was classified as highly accurate prediction results, because the MAPE value was less than 10%.*

Keywords— *Fourier Series Estimator, Bank Stock Price, Bank Central Asia.*

1. INTRODUCTION

The Indonesian capital market has become a crucial pillar in supporting the country's economic growth. As a major source of funding, the capital market offers a variety of investment instruments that allow economic actors to allocate their resources more efficiently. One of the most popular investment instruments is stocks. Stocks represent ownership in a company, entitling the holder to a share of the company's profits in the form of dividends, as well as the potential for gains from rising stock prices [1]. Additionally, stocks are a popular investment choice for many investors due to their ability to provide attractive returns [2].

Among the various sectors, the banking sector is one that attracts investors' attention. Investing in stocks of Indonesia's major banks is part of the effort to strengthen the financial sector, which is the foundation of stable economic development. Bank Central Asia (BCA) is one of Indonesia's leading banking companies with a large market capitalization and high liquidity levels [3]. BCA shares traded under the code BBCA are often the top choice for investors due to its reputation as a company with strong fundamentals [4]. Although BCA's share price has relatively more stability than other stocks, its share price still fluctuates.

Stock prices in the Indonesian capital market, including those of banking stocks like BCA, are influenced by both internal and external factors. Internal factors include the company's own conditions, such as its sales, financial performance, management, overall state, and the industry it operates in. Meanwhile, external factors are those outside the company's control, such as inflation, interest rates, exchange rates, as well as non-economic elements like social and political conditions [5]. These fluctuations often make it difficult for investors, especially inexperienced ones, to make the right investment decisions. Therefore, it is important for potential investors to have a more accurate prediction of stock price movements, including BCA shares as a consideration in making investment decisions.

One method that can be used to predict stock price movements is the Fourier series estimator. The Fourier series estimator is able to investigate unknown data patterns and there is a tendency for repeating data patterns [6]. The Fourier series estimator also has the advantage of being able to handle data with trigonometric distributions, in this case, sine and cosine [7]. Based on the flexibility and advantages of the Fourier series, this study aims to develop a BCA stock price prediction model that can assist investors in minimizing risk and maximizing the potential profit from BCA stock investments.

Several previous studies on the prediction of BCA Bank's share price have been conducted, including research conducted by [8] which predicts BCA Bank's share price after stock split with Artificial Neural Network (ANN) with Backpropagation Algorithm. The results showed that the ANN method was able to produce accurate predictions with an RMSE value of 121.16 and a MAPE of 1.12%. Then [9] predicted the stock price of BCA Bank using XGBoost which resulted in quite good accuracy with a MAPE of 4.01%. The application of Fourier analysis has been done by [10] to determine the period and prediction of air temperature. In addition, [11] also applied the Fourier series estimator to predict non-oil and gas export prices in Indonesia, which resulted in a fairly accurate prediction with a MAPE value of 15.26%.

This research offers an innovative approach by using a Fourier series estimator to predict BCA's stock price, a method that is relatively rarely used, especially in banking stock price prediction. The use of recent data (January 2022 - November 2024) strengthens the novelty of the research that allows analysis of fluctuating stock prices after the Covid 19 pandemic. The urgency of this research is that the research results are expected to provide accurate predictions that are useful for investors in making investment decisions and assist banks in formulating more effective long-term strategies, while contributing to the achievement of Sustainable Development Goals (SDGs) point 8, which is focused on Decent Work and Economic Growth.

2. Literature Review

2.1 PT. Bank Central Asia

PT Bank Central Asia Tbk (BCA) is the largest privately-owned bank in Indonesia, having been established on October 10, 1955, based on Decree No. J.A.5/89/19 approved by the Minister of Finance [12]. On May 31, 2000, BCA shares were officially listed and traded on the Indonesia Stock Exchange. In 2010, BCA became the first bank in Indonesia with a market value of Rp100 trillion. Today, BCA has assets of more than Rp1000 trillion, making it the largest bank in Indonesia. On June 8, 2020, Forbes published an article titled "The World's Best Banks: The Future of Banking is Digital After Coronavirus," which named BCA as the best bank in Indonesia. As of the end of March 2024, BCA has 1,258 branch offices spread across Indonesia [13].

2.2 Regression Analysis

According to [14], regression analysis is one of the methods in statistics used to identify the relationship between response and predictor variables. With paired data between predictor and response variables (x_i, y_i), the regression model can be expressed as follows

$$y_i = f(x_i) + \varepsilon_i \, , i = 1,2, \dots, n \, , \varepsilon_i \sim IIDN(0, \sigma^2) \qquad (1)$$

with n being the number of observations. In this context, the function $f(x_i)$ acts as the regression function, while ε_i is the error which is assumed to be identical, independent, and normally distributed with a mean of 0 and a variance of σ^2 [15].

2.3 Nonparametric Regression

Nonparametric regression is a statistical technique that serves to analyze the relationship between dependent (response) and independent (predictor) variables. This method is applied when the relationship between variables does not have a clear pattern or function shape. The use of nonparametric regression is chosen because there is no prior information about the shape of the function $m(x_t)$, as explained by [16]. In nonparametric regression there is a general equation model that is the basis for its calculation, the following is the general equation of nonparametric regression

$$y_t = m(x_t) + \varepsilon_t \, , t = 1,2, \dots, n \, , \varepsilon_t \sim IIDN(0, \sigma^2) \qquad (2)$$

In nonparametric regression, the function $m(x_t)$ is assumed to be smooth, which allows more flexibility in estimating the regression function. The error component (ε_t) fulfills the assumptions of being identical, independent, and following a normal distribution with mean 0 and variance σ^2. According to [17], there are various smoothing methods that can be used in nonparametric regression, including histogram, spline, kernel, and Fourier series estimators.

2.4 Fourier Series Estimator

The Fourier series estimator is one of the smoothing methods in nonparametric regression that is effectively used to analyze data with complex and repetitive patterns. When the shape of the pattern in the repeating data is not clearly known, the Fourier series can be the right solution to identify it [18]. In addition, the Fourier series is effective for describing curves that show sine and cosine waves [19]. In nonparametric regression using the Fourier approach, in addition to combining sine and cosine functions, an additive combination of linear functions derived from sine or cosine functions can also be used [20]. If the observation data is known (t_r, y_r) the general regression model is as follows.

$$y_r = m(t_r) + \varepsilon_r, \qquad r = 1,2,3, \dots, n \qquad (3)$$

The regression function $m(t_r)$ is of unknown form and will be estimated by Fourier series. It is assumed that $m(t_r) \in L_2[a,b]$ is contained in the Hilbert space as a linear combination of basis elements of $L_2[a,b]$ which can be expressed as follows.

$$m(t_r) = \sum_{j=1}^{\infty} \beta_j x_j \, (t_r) \qquad (4)$$

with β_j is a scalar, so the model can be written as follows.

$$y_r = \sum_{j=1}^{\infty} \beta_j x_j \, (t_r) \qquad (5)$$

Observation data is in the form of time and periodic functions, then to estimate the function equation (13) can use a linear model which has sine and cosine functions. Complex exponential functions can be expressed in terms of sine and cosine functions. The complex exponential function can be written as follows.

$$x_j(t_r) = e^{2\pi i j t_r} \qquad (6)$$

Then substitute equation (6) into equation (4) and obtain the following.

$$\hat{m}(t_r) = \sum_{j=-\lambda}^{\lambda} \hat{\beta}_j e^{2\pi i j t_r} \qquad (7)$$

with $e^{ix} = \cos(x) + i \sin(x)$ and $e^{-ix} = \cos(x) - \sin(x)$, the Fourier series estimator for $\hat{m}(t_r)$ is as follows.

$$\hat{m}(t_r) = \sum_{j=-\lambda}^{\lambda} \hat{\beta}_j e^{2\pi i j t_r}$$

$$\hat{m}(t_r) = \sum_{j=-\lambda}^{\lambda} \hat{\beta}_j e^{2\pi i j t_r} + \hat{\beta}_{(-j)} e^{2\pi i (-j) t_r}$$

$$\hat{m}(t_r) = \hat{\beta}_0 + \sum_{j=1}^{\lambda} \left(\hat{\beta}_j e^{2\pi i j t_r} + \hat{\beta}_{(-j)} e^{2\pi i (-j) t_r} \right)$$

$$\hat{m}(t_r) = \hat{\beta}_0 + \sum_{j=1}^{\lambda} \left[\hat{\beta}_j \left(\cos(2\pi j t_r) + i \sin(2\pi j t_r) \right) + \hat{\beta}_{(-j)} \left(\cos(2\pi j t_r) - i \sin(2\pi j t_r) \right) \right]$$

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$$\hat{m}(t_r) = \hat{\beta}_0 + \sum_{j=1}^{\lambda}\left[\left(\hat{\beta}_j + \hat{\beta}_{(-j)}\right)\cos(2\pi j t_r) - i\left(\hat{\beta}_j + \hat{\beta}_{(-j)}\right)\sin(2\pi j t_r)\right]$$

So that we get

$$\hat{m}(t_r) = \hat{\beta}_0 + \sum_{j=1}^{\lambda}\left[a_j\cos(2\pi j t_r) + b_j\sin(2\pi j t_r)\right] \quad (8)$$

with

$$a_j = \frac{2}{n}\sum_{r=1}^{n} y_r\cos(2\pi t_r)$$

$$b_j = \frac{2}{n}\sum_{r=1}^{n} y_r\cos(2\pi t_r)$$

$$t_r = \frac{t_i - 1}{n}$$

Next, substitute equation (8) into equation (3)

$$y_r = \hat{\beta}_0 + \sum_{j=1}^{\lambda}\left[a_j\cos(2\pi j t_r) + b_j\sin(2\pi j t_r)\right] + \varepsilon_r \quad (9)$$

with the regression curve estimator given as follows.

$$\hat{y}_r = \hat{\beta}_0 + \sum_{j=1}^{\lambda}\left[\hat{a}_j\cos(2\pi j t_r) + \hat{b}_j\sin(2\pi j t_r)\right] \quad (10)$$

2.5 Determination of Optimal Oscillation Parameters

One of the techniques used to determine the optimal oscillation parameter (λ) is Generalized Cross Validation (GCV). The oscillation parameter has the function of balancing the smoothness of the function and the fit to the data. The larger the value of λ, the coarser the function estimate, while the smaller the value of λ, the smoother the function estimate. Therefore, the selection of the optimal λ is very important to obtain the optimal estimator. For each λ, the form of the estimator $m(t)$ is as follows.

$$\hat{\mathbf{Y}} = \mathbf{H}_{\boldsymbol{\lambda}}\mathbf{Y} \quad (11)$$

The optimal λ selection results in the minimum GCV value for the Fourier series estimator as follows

$$GCV(\boldsymbol{\lambda}) = \frac{MSE(\boldsymbol{\lambda})}{(n)^{-1}trace[\mathbf{I} - \mathbf{H}_{\boldsymbol{\lambda}}])^2} \quad (12)$$

with

$MSE(\boldsymbol{\lambda}) = (n)^{-1}\boldsymbol{y}'(\mathbf{I} - \mathbf{H}_{\boldsymbol{\lambda}})\boldsymbol{y}$

2.6 Prediction Accuracy Criteria

To determine the most optimal time series model, several prediction accuracy measures can be used, including Mean Squared Error (MSE), Mean Absolute Percentage Error (MAPE), and R-Square, which are explained as follows.

Mean Squared Error (MSE) is a measure of accuracy calculated by averaging the squares of the difference between predicted and actual values. MSE is always positive. The smaller the MSE value, the more accurate the forecasting model. The following is the formulation for calculating the MSE value

$$MSE = \frac{1}{n}\sum_{t=1}^{n}(y_t - \hat{y}_t)^2 \quad (13)$$

with n is the number of data, y_t is the actual data, and $\hat{y}_t$ is the predicted data of the t-th observation

Mean Absolute Percentage Error (MAPE) is one of the accuracy measures used to evaluate the performance of a forecasting model. MAPE shows the average percentage error between predicted and actual values, making it easy to understand and interpret. The following is the formulation for calculating the MAPE value

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{y_t - \hat{y}_t}{y_t}\right| \times 100 \quad (14)$$

According to [21], MAPE values can be interpreted based on a certain range of values used to measure the performance of the resulting model. The following is the interpretation of the MAPE value presented in Table 1.

Table 1 Interpretation of MAPE Value

MAPE Value	Interpretation
$MAPE < 10\%$	Highly accurate forecasting results
$10\% \le MAPE \le 20\%$	Accurate forecasting results
$20 < MAPE \le 50\%$	Decent forecasting result
$MAPE > 50\%$	Poor forecasting result

To assess forecasting accuracy, one can also use the coefficient of determination (R^2). The R^2 value shows how well the model can explain variations in the data. The higher the R^2 value, the better the quality of the model. The R^2 value can be calculated with the following formulation

$$R^2 = 1 - \frac{\sum(y_i - \hat{y}_i)^2}{\sum(y_i - \bar{y})^2} \quad (15)$$

3. Research Methods

3.1 Data and Data Sources

The data used in this study are secondary data, obtained from the investing.com website. The data taken in the form of Bank Central Asia (BBCA) stock price data for the weekly period starting from January 2022 to November 2024 with a total of 150 data. The research data is divided with a proportion of 70% used as training data and 30% used as testing data. The research data structure is presented in Table 2 below

Table 2 Research Data Structure

Type of Observation Data	Response Variable (BCA Stock Price) y_t	Predictor Variable (Observation Time, t)
Training Data (70%)	y_1	1
	y_2	2
	⋮	⋮
	y_{105}	105
Testing Data (30%)	y_{106}	106
	y_{107}	107
	⋮	⋮
	y_{150}	150

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3.2 Data Analysis Procedures

The procedure or stages of analysis in this study are described as follows.

1. Creating a time series plot to illustrate the weekly stock price movement of BCA Bank.
2. The data is divided into training and testing subsets.
3. The optimal oscillation parameter (k) is determined based on the Minimum GCV (Generalized Cross-Validation) criterion for each of the sine, cosine, and cosine-sine functions.
4. Estimating the model based on the optimal oscillation parameter (k) value using training data.
5. Make predictions using testing data.
6. Calculate MSE, MAPE, and R-Square values for prediction accuracy criteria

4. Results and Discussion

4.1 BCA Stock Price Data Description

Descriptive statistical analysis of stock prices is carried out to determine the characteristics and fluctuations in stock prices in each period. In describing the distribution of data, the minimum, maximum, mean, and time series plot values are used. The following is a descriptive statistical analysis and time series plot of BCA's weekly stock prices for the period January 2022 to November 2024.

Figure 1 Time Series Plot Harga Saham BCA

Based on Fig. 1, shows that from January 2022 to November 2024, BCA's stock price fluctuates every week. This shows an indication of periodic symptoms, so the data is suitable for analysis using the Fourier series estimator.

Table 3 BCA Share Price Characteristics

Deskriptive Statistics	Value
Minimum	7000
Maximum	10775
Mean	8945,8

Based on Table 3, the average weekly share price from January 2022 to November 2024 is 8945.8. Then, the lowest BCA share price is 7000, namely in the second week period of July 2022 and the highest BCA share price is 10775, namely in the third week period of September 2024.

4.2 BCA Stock Price Modeling

Fig. 1 shows that there is no specific relationship pattern and shows a periodic pattern that resembles the distribution of trigonometric functions, in this case the sine and cosine functions, so the data is analyzed using the Fourier series estimator approach.

The best relationship model between response variables and predictor variables is obtained by determining the optimal oscillation parameter (λ) with minimum GCV criteria. The GCV value for BCA weekly stock price data for the period January 2022 - November 2024 is obtained as shown in Table 4 below.

Table 4 Optimal Lambda Value and GCV

Lambda (λ)	GCV Value
1	149620.4
2	106367.2
3	97159.63
4	91337.59
5	81420.9
6	72066.72
7	69956.2
8	70677.7
9	56982.12
10	59479.15
11	54928.91
12	53545.37
13	52417.18
14	51179.65
15	52788.93
16	51864.08
17	49052.54
18	49901.12
19	52759.49
20	52156

Based on Table 4, the optimal λ based on the minimum GCV value is 17. This optimal λ value will be used as the number of coefficients of the Fourier series equation and as a smoothing parameter for the Fourier series curve. The minimum GCV plot on BCA stock price data is shown in Fig. 2.

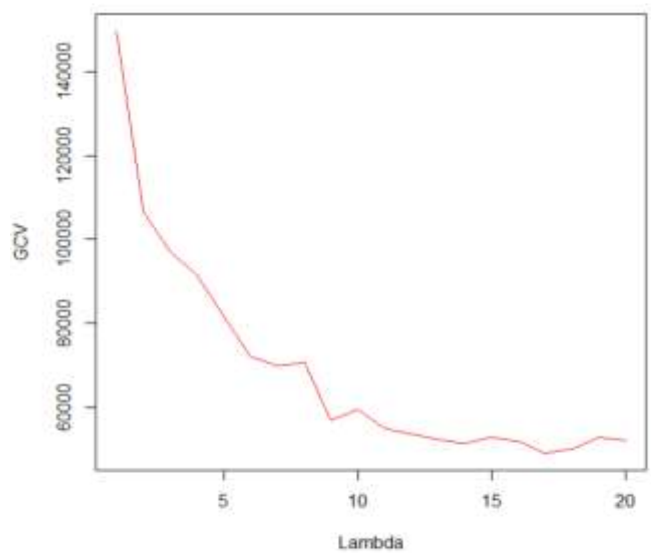

Figure 2 Lambda λ plot against GCV value

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Based on Fig. 2, the minimum GCV value is obtained at $\lambda = 17$, so it can be concluded that BCA stock price data has an optimal λ value of 17 with a minimum GCV value of 49502.54.

The next step is to calculate the value of Fourier parameters a_j as a cosine function and b_j as a sine function. The value of $\hat{\beta}_0$ for BCA stock price data is 8495. As for the values of $\lambda, a_j, dan\ b_j$ are shown in Table 5 below.

Table 5 Lambda $(\lambda), a_j, b_j$ Values

Lambda (λ)	a_j value	b_j value
1	−126.7973	−704.3056
2	101.4584	−281.3101
3	119.0504	97.51793
4	−94.79347	−87.09954
5	35.16117	−144.76
6	22.16417	−139.1613
7	21.19115	−86.08594
8	−51.07461	−29.92699
9	22.42623	−149.4455
10	13.08346	−12.1312
11	−7.319413	−95.28341
12	−56.73282	−40.20134
13	10.85026	−64.78327
14	−13.18218	−63.65241
15	30.48639	−16.03863
16	−54.92948	−25.47053
17	−37.001	−61.66096

Based on Table 3, the BCA weekly stock price data model for the period January 2022 to November 2024 can be written based on the Fourier series estimator approach as follows

$$\begin{aligned}\hat{y}_r = 8495 &- 126.8\cos(2\pi t_r) \\ &- 704.31\sin(2\pi t_r) \\ &+ 101.46\cos(4\pi t_r) \\ &- 281.31\sin(4\pi t_r) + \cdots \\ &- 37.001\cos(34\pi t_r) \\ &- 61.66\sin(34\pi t_r)\end{aligned} \tag{16}$$

4.3 Model Estimation Results

Based on the BCA Bank stock price data that has been analyzed, the optimal λ value is obtained with the smallest GCV value at the 17th λ value, which is 49502.54. The Fourier series estimation results on the training data using λ of 17 are depicted in Fig. 3 below.

Figure 3 Plot of Actual and Estimated Training Data

Based on Fig. 3, the estimation results obtained on the BCA weekly stock price training data are close to the original data with an MSE value of 21801.13, a MAPE value of 1.157475%, and an R-Square of 94.51205%.

The model that has been obtained based on equation (16) is then used to predict the testing data. The prediction results based on the best model are presented in Table 6 as follows.

Table 6 Prediction Value of Testing Data

Data to –	Actual Data	Predicted Data
1	9625	9653.393
2	9350	9374.262
3	9700	9627.999
4	9700	9799.536
5	9950	9852.721
6	9825	9890.235
7	9825	9811.394
8	10150	10109.73
9	10150	10227.67
10	10100	10015.07
11	10075	10133.26
12	9825	9819.777
13	9475	9417.24
14	9625	9735.945
15	9850	9712.024
16	9375	9506.326
17	9750	9655.388
18	9425	9466.004
19	9250	9261.628
20	9325	9277.99
21	9200	9255.944
22	9600	9560.971
23	9925	9930.776
24	9950	9979.422
25	10075	10022.16
26	10125	10181.41
27	10325	10284.7
28	10200	10212.24
29	10150	10165.9
30	10325	10292.03
31	10325	10357.84
32	10325	10308.59

Data to –	Actual Data	Predicted Data
33	10300	10290.81
34	10425	10458.92
35	10775	10725.83
36	10650	10701.27
37	10475	10432.1
38	10375	10406.58
39	10750	10723.85
40	10750	10782.52
41	10425	10374.37
42	10075	10148,87
43	10175	10083.66
44	9850	9942.252
45	10000	9929.384

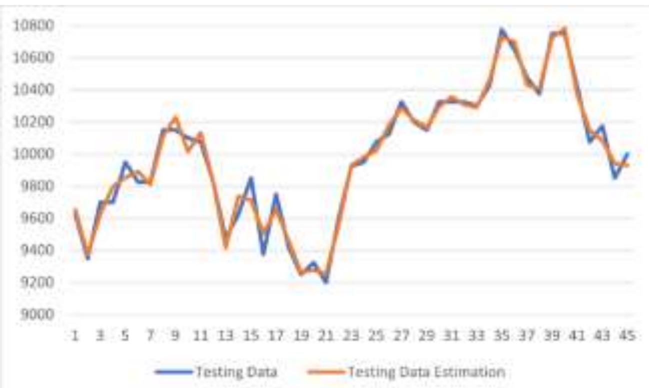

Figure 4 Plot of Actual Data and Estimated Testing Data

Based on Table 6 and Fig. 4 which is a table of prediction values on the testing data, which produces an MSE value of 3784.379, a MAPE value of 0.5249203%, and an R-Square value of 97.72247%. The MAPE value of the testing data is 0.5249203% where the value is classified as highly accurate prediction result criteria, because the MAPE value is less than 10%. Thus, the results of BCA's weekly stock price prediction using the Fourier series estimator method are very good for use in modeling and predicting BCA's weekly stock price in the future.

5. Conclusion

Based on the research results that have been described, it is concluded that modeling BCA weekly stock price data obtained an optimal λ value of 17. The modeling results are presented in the following equation.

$$\begin{aligned}\hat{y}_r = 8495 - 126.8\cos(2\pi t_r) - 704.31\sin(2\pi t_r) \\ + 101.46\cos(4\pi t_r) - 281.31\sin(4\pi t_r) \\ + \cdots - 37.001\cos(34\pi t_r) \\ - 61.66\sin(34\pi t_r)\end{aligned}$$

The best model produces prediction results that are close to the original data with an MSE value of 3784.379, a MAPE value of 0.5249203%, and an R-Square value of 97.72247%. It can be concluded that the results of modeling BCA's weekly stock price data with the Fourier series estimator show very accurate results periodically.

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