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Ismail Djakaria <iskar@ung.ac.id> — 4 Juni 2024 pukul 11.45
Kepada: sever.dragomir@ajmaa.org

Dear Editor,

I hope this message finds you well.

We are pleased to submit our manuscript titled "Indonesia's GDP Forecast: Evidence from Fuzzy Time Series Model Using Particle Swarm Optimization Algorithm" for consideration in The Australian Journal of Mathematical Analysis and Applications. We believe our findings offer significant insights and advancements in the field of economic forecasting using mathematical models.

Please find the manuscript attached to this email. We look forward to your review and hope for a favorable consideration for publication in your esteemed journal.

Thank you for your time and attention. Should you require any further information or have any questions, please do not hesitate to contact us.

Best regards,

Ismail Djakaria

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INDONESIA'S GDP FORECAST: EVIDENCE FROM FUZZY TIME SERIES MODEL USING PARTICLE SWARM OPTIMIZATION ALGORITHM

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Received xx Month, 202x; accepted yy Month, 202x; published zz Month, 202x.

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ABSTRACT. Gross Domestic Product (GDP) is a principal indicator used to measure the economic condition of a country. Indonesia's GDP growth from 2017 to 2019 was approximately 6 percent; however, it experienced a decline in 2020 and 2021, with rates of only -0.02 percent and 2.41 percent, respectively. In the process of economic development planning, a forecasting system is required to determine GDP in the future. The forecasting method employed in this research is fuzzy time series optimized using Particle Swarm Optimization (PSO), to enhance the accuracy and convergence of forecasted values. The dataset used comprises secondary data, specifically 54 sets of Indonesian GDP data spanning from the first quarter of 2010 to the second quarter of 2023. The analysis results indicate that the proposed method is better than the conventional fuzzy time series approach. The former method provides a predictive value for one period in the future with a Mean Absolute Percentage Error (MAPE) value of 4.40%. In contrast, the latter yields higher predictive values with a MAPE value of 7.93%.

Key words and phrases: forecasting model; gross domestic product; fuzzy time series; particle swarm optimization

2010 *Mathematics Subject Classification.* Primary xxxxx, xxxxx. Secondary xxxxx, xxxxx.

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1. Introduction

Gross Domestic Product (GDP) is one of the indicators used to measure the economic condition of a country. GDP includes the amount of goods and services produced by a nation's production units based on prevailing prices or constant prices. Growth with redistribution can lead to poverty and national inequality, as observed in other countries, such as the Philippines, between 2000 and 2018. Over the same 20-year period, nearly the entire territory of the country experienced growth. The growth rate experienced between 2012 and 2019 exceeded that of previous years. Economic expansion, however, has manifested unevenly across the region, with two conspicuous outliers. The National Capital Region (NCR) stands out as the most consistent economic player, maintaining a real GDP per capita of approximately 457,000 pesos (or around 8,823 USD) in 2019 [1]. One of the studies conducted in Nigeria [2] that aims to analyze or conduct studies on gross domestic income (GDI) and GDP, can reduce carbon emissions in the country. A substantial body of empirical and theoretical literature exists focusing on the impact of natural disasters, including forest fires, on GDP growth [3]. GDP serves as a prominent metric in economic accounting, commonly employed to assess the economic performance of countries and regions worldwide [4]. However, GDP lacks consideration for inclusivity and fails to furnish insights into the sustainability of economic growth [5]. The feature of providing broad consideration of the consequences of economic growth on a small (local) or global scale is needed to replace GDP in the SDG 8 indicators set to increase its coherence with the overall SDGs Agenda [6].

In planning economic development, it is essential to implement a forecast calculation system to project future GDP as a benchmark for the Indonesian economy. One applicable forecasting method is the fuzzy time series method. Through this forecasting approach, policymakers can develop and formulate more effective policies, thereby fostering a positive impact on development. This strategic use of forecasting facilitates economic development aimed at enhancing the population's welfare.

Forecasting in macroeconomics generally refers to the sequence of data related to the same statistical variable based on its chronological occurrence. The objective is to identify intrinsic relationships within the data through historical data analysis, enabling the prediction of future data points. The majority of time series modeling and forecasting involve the utilization of statistical regression models for continuous time series. Additionally, widely employed analysis models include Autoregressive Moving Average (ARMA) and Autoregressive Integrated Moving Average (ARIMA). For non-stationary time series, the initial step involves rendering it stationary through successive differencing. This process is commonly represented as a combination of white noise and moving average [7-11]. While these methods are widely recognized in economic forecasting, employing linear models, they may yield suboptimal results when applied to complex non-linear systems that aim to simulate real-life scenarios [12].

A method to address the aforementioned issue is the fuzzy time series-particle swarm optimization algorithm. Fuzzy time series are widely applied for forecasting in various cases, such as in the application of forecasting of air pollution time series data, with a new hybrid forecasting model that integrates fuzzy time series into Markov chains and C-Means clustering techniques with an optimal number of clusters [13], forecasting of weather, earthquakes, stock fluctuations and any phenomenon indexed by variables that change unexpectedly in time, given that classical time series methods cannot handle forecasting problems where time series values are linguistic terms represented by fuzzy sets [14], forecasting is therefore used as a new approach to present large time pools in a cluster, taking into account the dependencies of successive threads between times to obtain fuzzy partitions from pool observations [15, 16], forecasting subjective performance in engineering and construction management (CEM) issues, with a variety of suitable fuzzy hybrid techniques [17], forecasting coal mining production based on fuzzy-neural models [18], and in the application of fuzzy clustering to determine the distance between ordinal time series.

The proposed Fuzzy Time Series-Particle Swarm Optimization (FTS-PSO) algorithm introduces a novel approach to economic forecasting by seamlessly integrating two powerful techniques. The hybridization of Fuzzy Time Series (FTS) and Particle Swarm Optimization (PSO) leverages the strengths of each method to address critical challenges in forecasting. FTS, known for its adept handling of linguistic variables in representing qualitative information, forms the foundational component, allowing for nuanced interpretations of complex economic indicators. The PSO algorithm, operating synergistically, dynamically tunes key partitioning parameters of the FTS model during the optimization process. This adaptability not only enhances the accuracy of forecasting but also ensures the model's responsiveness to changes in the economic landscape. Importantly, FTS-PSO is explicitly designed to tackle the non-linear intricacies inherent in economic time series data, providing a more realistic representation of economic systems compared to traditional linear models. The algorithm's transparency and interpretability are preserved, allowing researchers and practitioners to trace each step of the decision-making process. Furthermore, the FTS-PSO algorithm showcases its versatility by demonstrating successful applications beyond GDP forecasting, spanning domains such as air pollution, weather, and stock fluctuations. In summary, FTS-PSO stands as an innovative and adaptive solution, contributing to the advancement of economic forecasting methodologies and offering a robust framework for addressing the complexities of diverse forecasting scenarios.

2. METHOD

The accuracy levels examined in this paper include the mean absolute percentage error (MAPE) and the Akaike information criterion (AIC). MAPE is commonly employed in modeling accuracy assessments due to its relatively straightforward interpretation of relative error. The merit of using the MAPE accuracy measure lies in its ease of comprehension and communication. It facilitates the presentation of results depicting the extent to which the estimate deviates from the actual average value, expressed in percentage terms. Consequently, MAPE assists in comparing model performance over a given timeframe, as long as the actual value does not approach zero closely. While the drawback is that MAPE can be affected by outliers or extreme values. For example, if there is an observation with a significantly large percentage of error, this can increase the accuracy value of MAPE [19-21]. Meanwhile, AIC serves as a criterion for selecting the optimal model, with the best model being characterized by the smallest AIC value.

The steps of forecasting for the fuzzy time series method are as employed by [22], [13]. This method decomposes the set of universes U into an equal number of intervals, $u_1, u_2, \ldots, u_n$. Through this step, fuzzy sets can be determined and fuzzified time series, which ultimately performs fuzzy logic relationship (FLR) modeling in fuzzification time series. The same steps are described [23].

- Describe the set of universes, U, and divide them into intervals of equal length. Assume $D_{\min}$ and $D_{\max}$ are the minimum and maximum residuals, respectively. Define $U = [D_{\min} - D_1, D_{\max} + D_2]$ where D_1 and D_2 are sustable positive numbers. When U is partitioned into n equal intervals

  $u_1, u_2, \ldots, u_n$, the length of the interval l, can be defined as $l = \frac{(D_{\max} + D_2 - (D_{\min} - D_1)}{n}$

- Determine fuzzy sets $A_1, A_2, \ldots, A_n$, as linguistic values of linguistic variables on the observed time series. Each A_i, where $i = 1, \ldots, n$ is defined by the intervals obtained in the step above and can be written as:

  $A_i = \ldots + 0/ u_i -2 + 0.5/ u_i -1 + 1/ u_i + 0.5/ u_i +1 + 0/ u_i +2 + \ldots$ (1).

  In Equation (1), the maximum membership value of A_i is contained in the interval u_i and so on.

- Calculate the forecast value for residuals based on FLR according to several methods, such as the method used by Chen, Yu, Cheng, and Lee.
- Calculate the final forecast value according to the forecast value obtained with the fuzzy model.

The steps of the calculation process are shown in the flowchart [24]. In this paper, the steps are carried out according to the following flowchart in Figure 1.

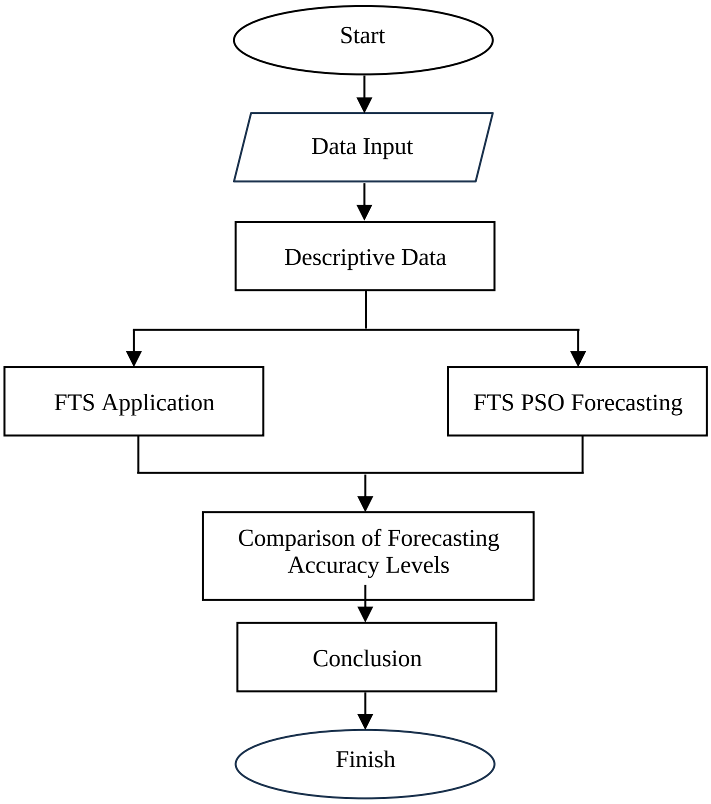

Figure 1. Flowchart of FTS PSO Forecasting Process Steps.

- Data Input: This stage involves collecting and organizing relevant data, such as historical time series data related to the phenomenon being studied. The quality and completeness of the input data play a crucial role in the accuracy of the forecasting model.

- Descriptive Data Analysis: Before applying any forecasting method, it's essential to analyze the descriptive statistics of the data. This includes measures like mean, median, standard deviation, and other statistical properties. Understanding the characteristics of the data helps in choosing appropriate modeling techniques.

- FTS Application: Fuzzy Time Series (FTS) involves capturing the uncertainty and fuzziness inherent in time series data. The application of FTS typically includes defining linguistic terms (e.g., low, medium, high), constructing fuzzy sets, and developing fuzzy rules that represent the patterns observed in the historical data.

- FTS PSO Forecasting Process Steps:

  Initialization: PSO starts with the initialization of a population of particles, each representing a potential solution. These particles are assigned random positions and velocities in the solution space.

  Objective Function Evaluation: The fuzzy time series model with PSO optimizes an objective function, which quantifies the accuracy of the forecasting model. This function takes into account the difference between the predicted values and the actual values from the historical data.

Updating Particle Positions: PSO updates the position and velocity of each particle based on its own best-known position and the best-known position of the entire swarm. This is done to search for the optimal solution in the solution space.

Fuzzy Rule Optimization: FTS, in combination with PSO, optimizes the fuzzy rules to enhance the forecasting accuracy. This step involves adjusting the parameters of the fuzzy rules to better fit the historical data patterns.

Iterative Optimization: The PSO algorithm iteratively refines the particle positions and fuzzy rule parameters to converge towards an optimal solution. This iterative process continues until a stopping criterion is met.

- Comparison of Forecasting Accuracy Levels: After applying the FTS with PSO forecasting method, the results are compared with other forecasting methods, presumably including standard FTS. This comparison is essential to assess the effectiveness and improvement achieved through the integration of Particle Swarm Optimization.
- Conclusion: The conclusion summarizes the findings, highlighting the strengths and weaknesses of the FTS with PSO forecasting approach. It may discuss the identified improvements in accuracy and provide insights into the practical implications of using this method for future predictions.
- Finish: The concluding section wraps up the study, potentially suggesting avenues for further research and application of the FTS with PSO forecasting model in different contexts. It may also discuss any limitations of the study and propose recommendations for future enhancements.

The proposed fuzzy time series model for forecasting Indonesia's GDP, incorporating a particle swarm optimization (PSO) algorithm, reveals notable limitations that impact its robustness and generalizability. Challenges arise from the model's susceptibility to partitioning parameters and the assumption of linearity in the relationship between linguistic variables and GDP within the complex economic landscape. The handling of outliers during the fuzzy logic relationship (FLR) modeling lacks explicit consideration, introducing uncertainties about the model's resilience to economic shocks. Additionally, dependence on a specific FLR method and subjective linguistic variable definitions may introduce biases, affecting forecast accuracy. Limited transparency in detailing the integration of the PSO algorithm raises concerns about the model's overall robustness.

To address these concerns, the study suggests an extension to explore alternative meta-heuristic algorithms, emphasizing the importance of a judicious selection and explicit justification. The extended methodology incorporates a broader range of forecasting models commonly used in economic prediction studies, such as autoregressive integrated moving average (ARIMA), exponential smoothing methods (e.g., Holt-Winters), and machine learning algorithms (e.g., regression models, support vector machines, or neural networks). This addition enables a more comprehensive evaluation of the performance of the fuzzy time series (FTS) and fuzzy time series with particle swarm optimization (FTSPSO) models. A rigorous evaluation strategy, employing performance metrics like mean absolute percentage error (MAPE) or root mean square error (RMSE) and statistical tests such as t-tests or ANOVA, is introduced to quantitatively assess the accuracy of each model. This enhanced methodology broadens the scope of the analysis, providing a more robust comparison and facilitating a clearer understanding of the relative strengths and weaknesses of the fuzzy time series models compared to other established forecasting techniques. The inclusion of explicit details on the alpha-cut type further contributes to a nuanced understanding of the methodology's intricacies, enhancing scholarly rigor.

3. Result and Discussion

The dataset employed in this study comprises Indonesia's quarterly Gross Domestic Product (GDP) data, measured in Billion Rupiahs at Current Market Prices by Industry. The data is sourced directly from the publication of the Central Bureau of Statistics. Specifically, the dataset spans from the first quarter of 2010 to the second quarter of 2023, covering a comprehensive timeframe for economic analysis. Table 1 provides a detailed breakdown of the quarterly GDP figures, offering a structured representation of the economic data used for the forecasting of Indonesia's GDP in this study.

Table 1. Indonesia's Quarterly GDP (Billion Rupiahs)

Index	Period	GDP Value	Index	Period	GDP Value
1	Q- I 2010	1,603,771.90	28	Q-IV 2016	3,193,903.80
2	Q-II 2010	1,704,509.90	29	Q- I 2017	3,228,172.20
3	Q-III 2010	1,786,196.60	30	Q-II 2017	3,366,787.30
4	Q-IV 2010	1,769,654.70	31	Q-III 2017	3,504,138.50
5	Q- I 2011	1,834,355.10	32	Q-IV 2017	3,490,727.70
6	Q-II 2011	1,928,233.00	33	Q- I 2018	3,510,363.10
7	Q-III 2011	2,053,745.40	34	Q-II 2018	3,686,836.40
8	Q-IV 2011	2,015,392.50	35	Q-III 2018	3,842,343.00
9	Q- I 2012	2,061,338.30	36	Q-IV 2018	3, 799,213.50
10	Q-II 2012	2,162,036.90	37	Q- I 2019	3,782,618.30
11	Q-III 2012	2,223,641.60	38	Q-II 2019	3,964,074.70
12	Q-IV 2012	2,168,687.70	39	Q-III 2019	4,067,358.00
13	Q- I 2013	2,235,288.50	40	Q-IV 2019	4,018,606.20
14	Q-II 2013	2,342,589.50	41	Q- I 2020	3,923,347.90
15	Q-III 2013	2,491,158.50	42	Q-II 2020	3,690,742.20
16	Q-IV 2013	2,477,097.50	43	Q-III 2020	3,897,851.90
17	Q- I 2014	2,506,300.20	44	Q-IV 2020	3,931,411.20
18	Q-II 2014	2,618,947.30	45	Q- I 2021	3,972,769.60
19	Q-III 2014	2,746,762.40	46	Q-II 2021	4,177,970.80
20	Q-IV 2014	2,697,695.40	47	Q-III 2021	4,327,358.00
21	Q- I 2015	2,728,180.70	48	Q-IV 2021	4,498,592.40
22	Q-II 2015	2,867,948.40	49	Q- I 2022	4,508,597.80
23	Q-III 2015	2,990,645.00	50	Q-II 2022	4,897,942.90
24	Q-IV 2015	2,939,558.70	51	Q-III 2022	5,066,994.30
25	Q- I 2016	2,929,269.00	52	Q-IV 2022	5,114,910.60
26	Q-II 2016	3,073,536.70	53	Q- I 2023	5,072,370.10
27	Q-III 2016	3,205,019.00	54	Q-II 2023	5,226,670.10

The above data plot can be shown in Figure 2.

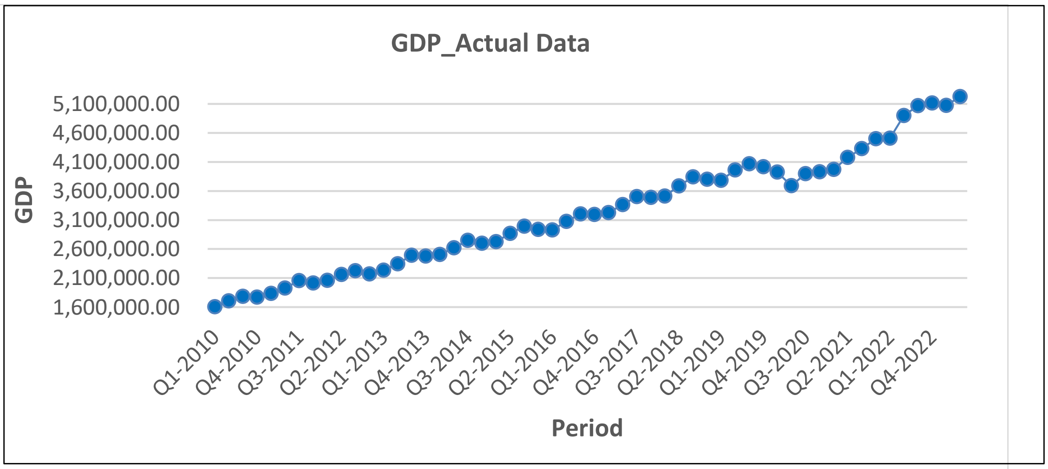

Figure 2. Indonesia's GDP Chart

Figure 2 presents a graphical representation of Indonesia's GDP data at Current Market Prices by Industry, measured in Billion Rupiahs, spanning from the first quarter of 2010 to the second quarter of 2022. The observed trend in the data pattern, as illustrated in the figure, indicates a discernible directional movement over the specified timeframe. This trend pattern provides valuable insights into the overall trajectory of Indonesia's economic output.

The minimum recorded data value occurred in the first quarter of 2010, registering at 1,603,771.90 billion Rupiahs. In contrast, the maximum value was documented in the second quarter of 2023, reaching IDR 5,226,670.10 billion. These extrema highlight the dynamic range of the GDP data, showcasing both the lowest and highest values within the given period.

The recognition of a discernible trend in the GDP data pattern serves as a rationale for considering the application of fuzzy time series for forecasting. The distinct fluctuations and directional movements in the data offer a foundation for exploring the potential of fuzzy time series methodology in capturing and predicting the intricate dynamics of Indonesia's economic output.

Fuzzy Time Series Analysis

The set of universes is derived from historical data through the establishment of minimum and maximum data bounds for the universes. In this context, specific parameters are defined to shape the universes: $d_1 = 0, d_2 = 100$, $D_{\min} = 1{,}603{,}771.90$, and $D_{\max} = 5{,}226{,}670.10$. These parameters lead to the formation of the universe set, denoted as $U = [1{,}603{,}771.90; 5{,}226{,}670.10]$.
To determine the number of intervals, K, the formula $K = 1 + 3.3 \cdot \log(54)$ is utilized, resulting in

K ≈ 6.7168, rounded to 7. Subsequently, fuzzy sets are derived by dividing the sum of intervals within U into K equal parts. Table 2 provides a clear representation of these fuzzy sets, delineating the intervals and corresponding linguistic values obtained from the historical data.

This systematic approach ensures a transparent explanation of the process involved in forming the set of universes, specifying the parameters used and how the intervals are determined. The subsequent representation in Table 2 further enhances the clarity of the derived fuzzy sets, establishing a foundation for the subsequent steps in the fuzzy time series modeling methodology.

Table 2. Fuzzy set

Interval	Lower Bound	Upper Bound	Middle Value	Fuzzy Set
U_1	1,603,771.90	2,121,343.07	1,862,557.49	A_1
U_2	2,121,343.07	2,638,914.24	2,380,128.66	A_2
U_3	2,638,914.24	3,156,485.41	2,897,699.83	A_3
U_4	3,156,485.41	3,674,056.59	3,415,271.00	A_4
U_5	3,674,056.59	4,191,627.76	3,932,842.17	A_5
U_6	4,191,627.76	4,709,198.93	4,450,413.34	A_6
U_7	4,709,198.93	5,226,770.10	4,967,984.51	A_7

After conducting a fuzzy time series analysis based on intervals, the set of speech universes and fuzzy sets obtained forecasting results, as shown in Table 3.

Table 3. Results of Indonesia's GDP Forecasting (Billion Rupiahs)

Period	GDP Value	Forecasting	Period	GDP Value	Forecasting
Q- I 2010	1,603,771.90	NA	Q-IV 2016	3,193,903.80	3,489,209.74
Q-II 2010	1,704,509.90	1,920,065.39	Q- I 2017	3,228,172.20	3,489,209.74
Q-III 2010	1,786,196.60	1,920,065.39	Q-II 2017	3,366,787.30	3,489,209.74
Q-IV 2010	1,769,654.70	1,920,065.39	Q-III 2017	3,504,138.50	3,489,209.74
Q- I 2011	1,834,355.10	1,920,065.39	Q-IV 2017	3,490,727.70	3,489,209.74
Q-II 2011	1,928,233.00	1,920,065.39	Q- I 2018	3,510,363.10	3,489,209.74
Q-III 2011	2,053,745.40	1,920,065.39	Q-II 2018	3,686,836.40	3,747,995.32
Q-IV 2011	2,015,392.50	1,920,065.39	Q-III 2018	3,842,343.00	3,972,655.34
Q- I 2012	2,061,338.30	1,920,065.39	Q-IV 2018	3,799,213.50	3,972,655.34
Q-II 2012	2,162,036.90	2,178,850.98	Q- I 2019	3,782,618.30	3,972,655.34
Q-III 2012	2,223,641.60	2,437,636.57	Q-II 2019	3,964,074.70	3,972,655.34
Q-IV 2012	2,168,687.70	2,437,636.57	Q-III 2019	4,067,358.00	3,972,655.34
Q- I 2013	2,235,288.50	2,437,636.57	Q-IV 2019	4,018,606.20	3,972,655.34
Q-II 2013	2,342,589.50	2,437,636.57	Q- I 2020	3,923,347.90	3,972,655.34
Q-III 2013	2,491,158.50	2,437,636.57	Q-II 2020	3,690,742.20	3,972,655.34
Q-IV 2013	2,477,097.50	2,437,636.57	Q-III 2020	3,897,851.90	3,972,655.34
Q- I 2014	2,506,300.20	2,437,636.57	Q-IV 2020	3,931,411.20	3,972,655.34
Q-II 2014	2,618,947.30	2,437,636.57	Q- I 2021	3,972,769.60	3,972,655.34
Q-III 2014	2,746,762.40	2,696,422.15	Q-II 2021	4,177,970.80	3,972,655.34

Q-IV 2014	2,697,695.40	2,962,396.23
Q- I 2015	2,728,180.70	2,962,396.23
Q-II 2015	2,867,948.40	2,962,396.23
Q-III 2015	2,990,645.00	2,962,396.23
Q-IV 2015	2,939,558.70	2,962,396.23
Q- I 2016	2,929,269.00	2,962,396.23
Q-II 2016	3,073,536.70	2,962,396.23
Q-III 2016	3,205,019.00	3,221,181.81
Q-III 2021	4,327,358.00	4,231,440.92
Q-IV 2021	4,498,592.40	4,622,937.07
Q- I 2022	4,508,597.80	4,622,937.07
Q-II 2022	4,897,942.90	4,881,722.65
Q-III 2022	5,066,994.30	4,967,984.51
Q-IV 2022	5,114,910.60	4,967,984.51
Q- I 2023	5,072,370.10	4,967,984.51
Q-II 2023	5,226,670.10	4,967,984.51

Referring to Table 3, the forecasted value for Indonesia's GDP in the upcoming period is projected to be 4,967,984.51 billion Rupiahs. This forecast is generated through the application of the fuzzy time series model, incorporating historical data and linguistic variables. The forecasted value provides an estimation of the economic output for the forthcoming period based on the established patterns and relationships identified in the historical GDP data.

Additionally, the Mean Absolute Percentage Error (MAPE) is calculated as 7.93%. MAPE is a measure of the accuracy of the forecasting model, representing the average percentage difference between the predicted and actual values. In this context, a MAPE of 7.93% suggests that, on average, the forecasted GDP values deviate by approximately 7.93% from the actual observed values. Lower MAPE values generally indicate a higher level of accuracy in the forecasting model.

Interpreting these results, the forecasted GDP value provides insight into the expected economic performance for the specified period, while the MAPE metric offers a quantitative measure of the accuracy of the forecasting model. A lower MAPE value indicates a more accurate forecast, implying that the fuzzy time series model has demonstrated a relatively precise ability to capture and predict the patterns in Indonesia's GDP data. However, it's essential to consider the specific context and requirements of the forecasting application when evaluating the adequacy of the model's performance.

Fuzzy Time Series using Particle Swam Optimization

Initial Parameter

The PSO parameters include the number of particles, commonly chosen within the range of multiples of 5 to 100, the number of iterations, the weight of iterations (w) starting from 0.5 to 1, and a combination of c1 and c2, subject to the condition that c1 + c2 ≤ 4. This paper adopts the PSO parameters as outlined in Table 4.

Table 4. PSO Parameter

No.	PSO Parameter	Value
1	Number of iteration	50
2	Number of particles	10
3	Weight of iteration	0.5
4	c_1	1.5
5	c_2	1.5
6	r_1	0.3
7	r_2	0.2

Position and initial velocity of particles

The initial velocity of each particle is assumed to be zero. The number of dimensions for the particles is determined by subtracting one from the total number of particles, i.e., 7 – 1 = 6 dimensions. The initial velocities of the particles are presented in Table 5.

Table 5. The Initial Velocity of The Particle

No.	d_1	d_2	d_3	d_4	d_5	d_6
1	0	0	0	0	0	0
2	0	0	0	0	0	0

3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0

The initial positions of each particle in the particle swarm optimization (PSO) algorithm are determined through a random generation process. The generated positions are constrained within the historical data bounds, specifically ranging from 1,603,771.90 to 5,226,770.10. It's worth noting that the values of both lower and upper bounds (1,603,771.90 and 5,226,770.10, respectively) are fixed and not included in the randomly generated positions.

Table 6 presents a detailed overview of these initial positions for each particle. The values listed in the table represent the randomly generated positions within the specified data bounds. The initial positions play a crucial role in initiating the PSO algorithm, influencing how particles explore the solution space in search of optimal parameter values for the fuzzy time series model.

Table 6. The Initial Position of The Particle

No.	d_1	d_2	d_3	d_4	d_5	d_6
1	,776,329.23	2,263,802.21	3,073,536.70	4,007,008.01	4,167,338.76	4,072,169.66
2	1,776,329.23	2,117,436.47	3,105,219.27	4,008,606.11	4,018,555.28	4,117,270.83
3	,821,067.72	2,078,418.32	3,187,813.82	4,023,347.91	3,923,347.14	4,027,458.72
4	,869,224.63	2,272,514.26	3,238,273.42	3,690,742.24	3,890,732.21	4,328,512.42
5	,831,747.26	2,723,541.26	3,476,787.64	3,897,851.97	4,067,358.14	4,408,398.63
6	,977,333.08	2,216,768.82	3,476,787.64	3,978,611.23	4,218,006.32	4,897,942.61
7	,869,224.63	2,352,344.53	3,476,787.64	4,009,678.03	4,013,447.33	5,102,124.13
8	,879,114.12	2,352,344.53	3,523,363.12	4,118,504.22	4,190,732.29	5,111,211.64
9	,872,671.12	2,352,344.53	3,523,363.12	4,254,348.54	4,767,458.44	5,272,381.41
10	,946,373.10	2,486,123.61	3,847,443.37	4,093,642.25	4,518,706.18	5,204,113.14

Fuzzy time series PSO

Optimum results of wide fuzzy time series intervals with PSO with the help of *Rstudio software.*

```
> pso_fts <- psoptim(fts_function, n=10, max.loop=50, w, c1, c2, xmin=xmin, xmax=xmax, vmax=c(2, 2), seed=5, anim=TRUE)
There were 50 or more warning (use warning() to see the first 50)
>
> pso_fts
$sol
             x1
[1,] 3625478.38

$val
[1] 5013524.47

>
> opt_interval <- sort(fts_function(fts_function(pso_fts$sol))
> opt_interval
[1] 1632199.23  2250184.80  2776079.46  3424865.36  3719698.16  4748846.20
>
```

Figure 3. Output Interval PSO

In Figure 3, the Particle Swarm Optimization (PSO) algorithm yields an optimum solution for the fuzzy time series model, resulting in a forecasted GDP value of 3,625,478.38. This optimal solution corresponds to a fitness value of 5,013,524.47. Additionally, the PSO algorithm identifies an optimal set of intervals for the fuzzy time series model, which is determined as follows: 1,632,199.23; 2,250,184.80; 2,776,079.46; 3,424,865.36; 3,719,698.16; 4,748,846.20.

These optimal intervals are then used to form fuzzy sets denoted as A_1, A_2, ..., A_7. Each fuzzy set interval is defined based on the identified optimum values and is represented as $A_1 = (D_{\min} - d_1, x_1)$, $A_2 = (x_1, x_2)$, ..., $A_7 = (x_6, D_{\max} + d_2)$, where x_1 to x_6 is the determined interval boundaries. The resulting fuzzy sets, along with their respective intervals, are organized and presented in Table 7.

Table 7. Fuzzy Set Interval

Fuzzy set	Lower Bound	Upper Bound	Middle Value
A_1	1,603,771.90	1,632,199.23	1,617,985.57
A_2	1,632,199.23	2,250,184.80	1,941,192.02
A_3	2,250,184.80	2,776,079.46	2,513,132.13
A_4	2,776,079.46	3,424,865.36	3,100,472.41
A_5	3,424,865.36	3,719,698.16	3,572,281.76
A_6	3,719,698.16	4,748,846.20	4,234,272.18
A_7	4,748,846.20	5,226,670.10	4,987,758.15

After conducting fuzzy time series analysis based on fuzzy set intervals PSO forecasting results are shown in Table 8.

Table 8. Fuzzy Time Series_PSO Forecasting Results

Period	GDP Value	Forecasting	Period	GDP Value	Forecasting
Q- I 2010	1,603,771.90	NA	Q-IV 2016	3,193,903.80	3,221,181.81
Q-II 2010	1,704,509.90	1,812,287.65	Q- I 2017	3,228,172.20	3,221,181.81
Q-III 2010	1,786,196.60	2,246,097.50	Q-II 2017	3,366,787.30	3,221,181.81
Q-IV 2010	1,769,654.70	2,246,097.50	Q-III 2017	3,504,138.50	3,221,181.81
Q- I 2011	1,834,355.10	2,246,097.50	Q-IV 2017	3,490,727.70	3,982,655.34
Q-II 2011	1,928,233.00	2,246,097.50	Q- I 2018	3,510,363.10	3,982,655.34
Q-III 2011	2,053,745.40	2,246,097.50	Q-II 2018	3,686,836.40	3,982,655.34
Q-IV 2011	2,015,392.50	2,246,097.50	Q-III 2018	3,842,343.00	3,982,655.34
Q- I 2012	2,061,338.30	2,246,097.50	Q-IV 2018	3,799,213.50	3,982,655.34
Q-II 2012	2,162,036.90	2,246,097.50	Q- I 2019	3,782,618.30	3,982,655.34
Q-III 2012	2,223,641.60	2,246,097.50	Q-II 2019	3,964,074.70	3,982,655.34
Q-IV 2012	2,168,687.70	2,246,097.50	Q-III 2019	4,067,358.00	3,982,655.34
Q- I 2013	2,235,288.50	2,246,097.50	Q-IV 2019	4,018,606.20	3,982,655.34
Q-II 2013	2,342,589.50	2,246,097.50	Q- I 2020	3,923,347.90	4,444,340.92
Q-III 2013	2,491,158.50	2,246,097.50	Q-II 2020	3,690,742.20	4,444,340.92
Q-IV 2013	2,477,097.50	2,246,097.50	Q-III 2020	3,897,851.90	4,444,340.92
Q- I 2014	2,506,300.20	2,772,645.24	Q-IV 2020	3,931,411.20	4,444,340.92
Q-II 2014	2,618,947.30	2,772,645.24	Q- I 2021	3,972,769.60	4,444,340.92
Q-III 2014	2,746,762.40	2,772,645.24	Q-II 2021	4,177,970.80	4,444,340.92
Q-IV 2014	2,697,695.40	2,772,645.24	Q-III 2021	4,327,358.00	4,444,340.92
Q- I 2015	2,728,180.70	2,772,645.24	Q-IV 2021	4,498,592.40	4,743,338.12
Q-II 2015	2,867,948.40	2,772,645.24	Q- I 2022	4,508,597.80	4,743,338.12
Q-III 2015	2,990,645.00	2,772,645.24	Q-II 2022	4,897,942.90	4,743,338.12
Q-IV 2015	2,939,558.70	2,772,645.24	Q-III 2022	5,066,994.30	5,116,852.62
Q- I 2016	2,929,269.00	2,772,645.24	Q-IV 2022	5,114,910.60	5,116,852.62
Q-II 2016	3,073,536.70	3,221,181.81	Q- I 2023	5,072,370.10	5,116,852.62
Q-III 2016	3,205,019.00	3,221,181.81	Q-II 2023	5,226,670.10	5,116,852.62

Referring to Table 8, the forecasted value for Indonesia's GDP in the upcoming period (Q-III 2023) is projected to be 5,116,852.62 billion Rupiahs. This forecast is derived from the fuzzy time series model, which incorporates the optimized parameters obtained through the Particle Swarm Optimization (PSO) algorithm. The forecasted value represents an estimate of the economic output for the specified future period, based on the identified patterns and linguistic representations in the historical GDP data.

The fuzzy time series model, with the optimized intervals determined by PSO, contributes to a more accurate and refined forecasting process. The forecasted GDP value of 5,116,852.62 billion Rupiahs provides valuable insights for decision-makers, analysts, and stakeholders, aiding in anticipating and planning for the economic performance of Indonesia in Q-III 2023. This output represents the culmination of the fuzzy time series modeling and optimization efforts, offering a quantified projection for the specified period.

Comparison of fuzzy time series and fuzzy time series PSOs

The comparison of the accuracy of fuzzy time series and fuzzy time series PSO forecasting are the AIC and MAPE. The results of AIC and MAPE values can be seen in Table 9.

Table 9. Comparison of Forecasting Results

Method	AIC	MAPE
Fuzzy time series	2773.32	7.93%
Fuzzy time series PSO	2137.21	4.40%

Based on the findings in Table 9, it is evident that the fuzzy time series method combined with PSO outperforms the conventional fuzzy time series, as indicated by its smaller error value (MAPE). A representation of the accuracy comparison between fuzzy time series and fuzzy time series forecasting with PSO is presented in Figure 4.

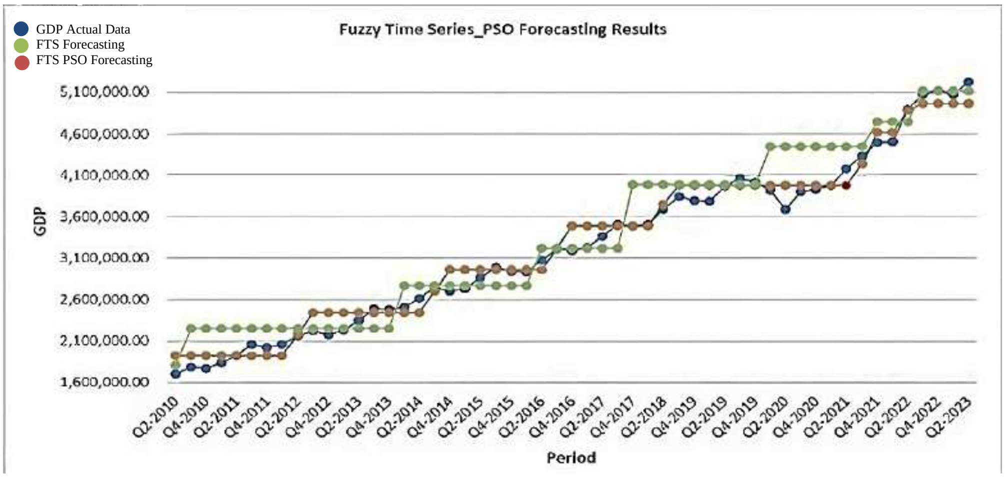

Figure 4. Fuzzy time series PSO Forecasting of Indonesia's GDP

Figure 4 illustrates that the integration of the Particle Swarm Optimization (PSO) algorithm with the fuzzy time series method leads to an enhanced performance compared to the standard fuzzy time series alone. The plot demonstrates a closer alignment between the forecasted values obtained through the fuzzy time series method with PSO optimization and the actual Indonesia's GDP data. This closer alignment signifies that the optimized parameters, obtained through the PSO algorithm, contribute to a more accurate representation of the underlying patterns in the GDP data.

The overall conclusion drawn from this observation is that the combined approach, incorporating PSO for parameter optimization, improves the forecasting accuracy of the fuzzy time series model. The enhanced alignment between the forecasted values and the actual data suggests that the optimized parameters allow the model to capture and represent the complex dynamics of Indonesia's GDP more effectively. This outcome reinforces the value of meta-heuristic optimization techniques, such as PSO, in refining the fuzzy time series methodology for robust economic forecasting.

In summary, the results and discussions affirm that the integration of PSO with the fuzzy time series model is a promising approach for improving the accuracy of GDP forecasts. This finding holds significance for practitioners, policymakers, and researchers involved in economic forecasting, providing insights into effective methodologies for capturing and predicting the intricate dynamics of Indonesia's economic landscape.

4. CONCLUSION

Based on the comprehensive results and discussions, a robust conclusion can be drawn regarding the fuzzy time series predictions for Indonesia's GDP using particle swarm optimization (FTS-PSO). The model, optimized through the particle swarm optimization algorithm, successfully identified seven intervals that span the dynamic range from the lower limit of 1,603,771.90 to the upper limit of 5,226,770.10 in the historical data. The forecasted GDP value using FTS-PSO is 5,116,852.62 billion Rupiahs, with a remarkably low Mean Absolute Percentage Error (MAPE) value of 4.40%.

In comparison, the forecasting results for Indonesia's GDP using the standard fuzzy time series alone yielded a predicted value of 4,967,984.51 billion Rupiahs, accompanied by a higher MAPE value of 7.93%. This stark difference in MAPE values underscores the superiority of the FTS-PSO approach, as it demonstrates a significantly lower percentage deviation between the predicted and actual values.

The original theoretical and technical contributions of this paper lie in the successful integration of particle swarm optimization with fuzzy time series for GDP forecasting. The FTS-PSO model outperforms the standard fuzzy time series model, providing a more accurate representation of Indonesia's economic dynamics. This research contributes to the field by showcasing the effectiveness of meta-heuristic optimization, particularly PSO, in refining fuzzy time series models for enhanced accuracy in economic forecasting. The identification of optimized intervals and the subsequent reduction in MAPE value highlight the practical implications of this approach for policymakers, analysts, and researchers engaged in economic prediction. Overall, this paper adds valuable insights to the methodology of economic forecasting, emphasizing the potential of combining fuzzy time series with meta-heuristic algorithms for superior predictive performance.

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We are keen to learn any feedback from the reviewers and the editorial team. If there are any additional details or materials required from our side to facilitate the review process, please let us know, and we will be happy to provide them promptly.

Thank you for your attention to this matter. We appreciate your time and efforts in handling our submission and look forward to your response.

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Thank you for your attention, and we look forward to your response.

Best regards,
Ismail Djakaria

[Kutipan teks disembunyikan]

Ismail Djakaria <iskar@ung.ac.id>

Request for Manuscript Review and Feedback, also Invoice for APC Payment

Ismail Djakaria <iskar@ung.ac.id> 3 Oktober 2024 pukul 14.25
Kepada: Sever Dragomir <sever.dragomir@ajmaa.org>, assistant.editor@ajmaa.org, sergiu.dragomir@ajmaa.org

Dear Editor,

I hope this email finds you well. We are delighted to know that our manuscript entitled *"Indonesia's GDP Forecast: Evidence from Fuzzy Time Series Model Using Particle Swarm Optimization Algorithm"* has been accepted for publication in the *Australian Journal of Mathematical Analysis and Applications*. However, we have not yet received the review feedback regarding our manuscript.

Could you kindly provide us with the reviewed file and the invoice for the publication? We would appreciate it greatly.

Thank you for your attention, and we look forward to your response.

Best regards,
Ismail Djakaria

Ismail Djakaria <iskar@ung.ac.id>

Request for Manuscript Review and Feedback, also Invoice for APC Payment

Sever Dragomir <sever.dragomir@ajmaa.org> 4 Oktober 2024 pukul 04.30
Kepada: Ismail Djakaria <iskar@ung.ac.id>, assistant.editor@ajmaa.org, sergiu.dragomir@ajmaa.org

Dear Professor Djakaria,

The Assistant Editor was in Spring holyday and will return soon to send you the invoice.

The review will be sent to you after you paid the OA fees and the payment is cleared.

Best regards,

Sever Dragomir

[Kutipan teks disembunyikan]

Ismail Djakaria <iskar@ung.ac.id>

Acceptance, Invoice Open Access and Template

Assistant Editor <assistant.editor@ajmaa.org> 5 Oktober 2024 pukul 14.55
Balas Ke: assistant.editor@ajmaa.org
Kepada: Ismail Djakaria <iskar@ung.ac.id>

Dear Dr. Djakaria,

Attached is an invoice for the publication fees of your paper. Please let us know if you require any change to the details of the invoice so we can send an updated copy.

Please complete the payment using one of the methods described in the invoice. Once we receive the payment for the attached invoice we will prepare your paper send you the proofs for any corrections required prior to publication.

If you need to make your payment through credit card, please let me know. I will be able to prepare an alternative invoice through PayPal, which can be paid via credit card. Please note this will carry a 3.0% surcharge.

Please also send us the latex files of your paper in our format so we can begin preparation once we receive your payment.

Sincerely,

Camelia Crepelca
Assistant Editor
AJMAA

From: Sever Dragomir [mailto:sever.dragomir@ajmaa.org]
Sent: Tuesday, 01 October, 2024 07:59
To: 'Ismail Djakaria'
Cc: assistant.editor@ajmaa.org
Subject: Acceptance, Invoice Open Access and Template

[Kutipan teks disembunyikan]

Invoice_Ismail_Djakaria.pdf
42K

UNGMail

Ismail Djakaria <iskar@ung.ac.id>

Acceptance, Invoice Open Access and Template

Ismail Djakaria <iskar@ung.ac.id> 7 Oktober 2024 pukul 12.36
Kepada: assistant.editor@ajmaa.org

Dear Editor,

I hope this email finds you well. We would like to inform you that we will proceed with the APC payment soon, and we kindly request you provide a PayPal invoice for the transaction.

Before we complete the payment, could you please confirm the publication date for our article? It is important for us that the article is published before October 10, 2024, as we are working with a tight deadline.

We appreciate your assistance and look forward to your response.

Best regards,
Ismail Djakaria

Universitas Negeri Gorontalo UNGMail

Ismail Djakaria <iskar@ung.ac.id>

Request for PayPal Invoice and Publication Date Confirmation

Ismail Djakaria <iskar@ung.ac.id> 7 Oktober 2024 pukul 13.39
Kepada: Sever Dragomir <sever.dragomir@ajmaa.org>, assistant.editor@ajmaa.org

Dear Editor,

I hope this email finds you well. We would like to inform you that we will proceed with the APC payment soon, and we kindly request you to provide a PayPal invoice for the transaction.

Before we complete the payment, could you please confirm the publication date for our article? It is important for us that the article is published before October 10, 2024, as we are working with a tight deadline.

We appreciate your assistance and look forward to your response.

Best regards,
Ismail Djakaria

Austral Internet Publishing

A. C. N. 636 962 573
PTY LTD
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Suite 148/ Level 2
66 Victor Crescent,
Narre Warren VIC 3805

TAX INVOICE

Invoice Date: 07/10/2024
Invoice: AJMAA - **10169**

To: Ismail Djakaria

Description:

AJMAA Journal Open Access Fee for:

Indonesia's GDP Forecast: Evidence from Fuzzy Time Series Model Using Particle Swarm Optimization Algorithm

Total Due:	**$1,025.00 AUD**
Due Date:	**31/10/2024**

Methods of Payment:

The payment should be made using either direct account transfer or PayPal in Australian dollars only. Credit card payments can be made via PayPal method.

Option 1. Direct transfer.

Bank Name & Address:	**Australia and New Zealand Banking Group Limited (ANZ)**
Account Name:	**A. C. N. 636 962 573 PTY LTD**
Branch (BSB)	**013 414**
Account No:	**150 422 276**
IBAN	**013414150422276**
International SWIFT code:	**ANZBAU3M**
Reference:	**AJMAA-10169**

IBANs are not used in Australia. However, payers in certain countries may require one. In that case, the BSB and account number should be combined. Do not include any spaces or hyphens. e.g. **013414150422276**

Note: Please use the Reference above on all internet deposits. Thank you.

Option 2. PayPal (inc Venmo, Credit Card, and more).
Available upon request. Please note this attracts a surcharge.

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Ismail Djakaria <iskar@ung.ac.id>

Invoice from Austral Internet Publishing (#AJMAA-2024)

Austral Internet Publishing <service@paypal.com.au> 9 Oktober 2024 pukul 16.38
Balas Ke: Austral Internet Publishing <assistant.editor@ajmaa.org>
Kepada: "iskar@ung. ac. id" <iskar@ung.ac.id>

Hello, iskar@ung.ac.id

Here's your invoice

Austral Internet Publishing sent you an invoice for $1,050.00 AUD

Due on receipt.

Invoice details

Amount requested
$1,050.00 AUD

Note from seller
Dear Dr Djakaria, this is your PayPal invoice. This can be paid through a Credit Card. Kind regards, Camelia Crepelca.

Invoice number
#AJMAA-2024

View and Pay Invoice

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Before paying, make sure you recognise this invoice. If you don't, report it. Learn more about common security threats and how to spot them. For example, PayPal would never use an invoice or a money request to ask you for your account credentials.

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Ismail Djakaria <iskar@ung.ac.id>

Request for PayPal Invoice and Publication Date Confirmation

Assistant Editor <assistant.editor@ajmaa.org> 9 Oktober 2024 pukul 17.38
Balas Ke: assistant.editor@ajmaa.org
Kepada: Ismail Djakaria <iskar@ung.ac.id>, Sever Dragomir <sever.dragomir@ajmaa.org>

Dear Dr. Djakaria,

The earliest possible publication date for your paper is 25 October. I have sent you a PayPal invoice that can be paid using a credit card.

Sincerely,

Camelia Crepelca
Assistant Editor
AJMAA

From: Ismail Djakaria [mailto:iskar@ung.ac.id]
Sent: Monday, 07 October, 2024 16:40
To: Sever Dragomir; assistant.editor@ajmaa.org
Subject: Request for PayPal Invoice and Publication Date Confirmation

[Kutipan teks disembunyikan]

Request for PayPal Invoice and Publication Date Confirmation

Ismail Djakaria <iskar@ung.ac.id>
Kepada: assistant.editor@ajmaa.org

28 Oktober 2024 pukul 15.35

Dear Editor,

We have received the PayPal invoice for our manuscript, and we appreciate your prompt handling of our submission. However, we are currently hesitant to proceed with the payment as we have not yet received the review results.

Given that this article is intended to support a promotion, we seek assurance that the review will focus on substantial content rather than primarily technical aspects, such as formatting, references, and template adherence. A review that thoroughly evaluates the article's originality, contribution to the field, and depth of analysis is essential for this purpose.

Could you provide us with insight into the focus of the review process for our submission? Any information about the depth and scope of the feedback we might expect would be immensely helpful as we move forward.

Thank you for your understanding and assistance. We look forward to your guidance.

Best regards,

Ismail Djakaria

Ismail Djakaria <iskar@ung.ac.id>

Request for PayPal Invoice and Publication Date Confirmation

Assistant Editor <assistant.editor@ajmaa.org> 29 Oktober 2024 pukul 17.24
Balas Ke: assistant.editor@ajmaa.org
Kepada: Ismail Djakaria <iskar@ung.ac.id>
Cc: Sever Dragomir <sever.dragomir@ajmaa.org>

Dear Dr. Djakaria,

The editorial office is responsible for only technical aspects of your paper once the paper has been accepted. Any additional comments from the review process would be available from Professor Dragomir.

At this stage, however, we are concerned with the intense need for an immediate publication, followed by lack of communication when we defined a possible timeline (which has now passed). We look forward to an explanation.

Best regards,

Camelia Crepelca
Assistant Editor
AJMAA

Ismail Djakaria <iskar@ung.ac.id>

Request for PayPal Invoice and Publication Date Confirmation

Ismail Djakaria <iskar@ung.ac.id> 30 Oktober 2024 pukul 15.44
Kepada: assistant.editor@ajmaa.org

Dear Dr. Crepelca,

I apologize for any miscommunication or delay on our end regarding the proposed timeline.
We would like to inform you that we are in the process of completing the article processing payment shortly. In addition, could you please provide us with an estimated timeline for the review result after payment and the updated publication schedule (which has now passed)? We are particularly interested in ensuring that the article undergoes a thorough substantive review prior to publication, as we aim for a comprehensive assessment of the manuscript's contributions.

Thank you again for your support.

Warm regards,
Ismail Djakaria

[Kutipan teks disembunyikan]

UNGMail

Ismail Djakaria <iskar@ung.ac.id>

Request for PayPal Invoice and Publication Date Confirmation

Assistant Editor <assistant.editor@ajmaa.org> 30 Oktober 2024 pukul 16.05
Balas Ke: assistant.editor@ajmaa.org
Kepada: Ismail Djakaria <iskar@ung.ac.id>
Cc: Sever Dragomir <sever.dragomir@ajmaa.org>

Dear Dr. Djakaria,

The review process does not necessarily produce a result that is shared with the Author. That is left up to the reviewer and their communication with the editorial office.

The only information regarding your paper that we have at this stage is that is has been accepted for publication. Any required corrections would be communicated through the editor in chief, but I am not aware of any.

Once your paper has been paid and we have received the LaTeX files, there may additional issues that we raise -- which generally fall in the "technical" area you mentioned.

Regarding potential publication timeline, it depends, it generally takes between 2 and 4 weeks from the time we have received your payment and files, depending on how closely your paper matches our style and the previously mentioned corrections.

Sincerely,

Camelia Crepelca
Assistant Editor
AJMAA

From: Ismail Djakaria [mailto:iskar@ung.ac.id]
Sent: Wednesday, 30 October, 2024 19:45
[Kutipan teks disembunyikan]

[Kutipan teks disembunyikan]

Ismail Djakaria <iskar@ung.ac.id>

Payment Proof and LaTeX File for Accepted Article

Ismail Djakaria <iskar@ung.ac.id> 8 November 2024 pukul 16.27
Kepada: Sever Dragomir <sever.dragomir@ajmaa.org>, assistant.editor@ajmaa.org

Dear Editors,

We hope this message finds you well. We are pleased to inform you that we have completed the payment for our accepted article entitled "Indonesia's GDP Forecast: Evidence from Fuzzy Time Series Model Using Particle Swarm Optimization Algorithm" for publication in AJMAA.

We have attached the payment proof below for your reference. Additionally, we have attached the LaTeX file of the article as requested. **Thus, we want to request a formal Letter of Acceptance of our article.**

Please do not hesitate to let us know if you require any further information or if there are additional steps needed to proceed with the publication process.

Thank you for your continued support and assistance.

Best regards,
Ismail Djakaria

2 lampiran

WhatsApp Image 2024-11-08 at 5.09.32 PM.jpeg
106K

AJMAATemplate.docx
564K

Ismail Djakaria <iskar@ung.ac.id>

Payment Proof and LaTeX File for Accepted Article

Sever Dragomir <sever.dragomir@ajmaa.org> 11 November 2024 pukul 12.33
Kepada: Ismail Djakaria <iskar@ung.ac.id>, assistant.editor@ajmaa.org

Dear Professor Djakaria,

Please find enclosed the formal acceptance letter and the referee's report on your paper below.

Sincerely,

Sever Dragomir,

Editor in Chief, AJMAA

[Kutipan teks disembunyikan]

2 lampiran

AcceptanceLetter.pdf
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RefereeReport.pdf
88K

UNGMail

Ismail Djakaria <iskar@ung.ac.id>

Payment Proof and LaTeX File for Accepted Article

Ismail Djakaria <iskar@ung.ac.id> 11 November 2024 pukul 13.49
Kepada: Sever Dragomir <sever.dragomir@ajmaa.org>

Dear Editor,

Thank you for your email. Further, we would like to know the estimated publication timeline. Additionally, if feasible, we would be grateful if the article could be scheduled for publication this month.

Thank you for your assistance, and please let us know if there is anything we can provide or complete to facilitate this process.

Best regards,

Ismail Djakaria

[Kutipan teks disembunyikan]

Ismail Djakaria <iskar@ung.ac.id>

Payment Proof and LaTeX File for Accepted Article

Sever Dragomir <sever.dragomir@ajmaa.org> 11 November 2024 pukul 14.05
Kepada: Ismail Djakaria <iskar@ung.ac.id>
Cc: assistant.editor@ajmaa.org

The assistant editor will interact with you regarding the timing of the publication. Is nothing I can do.

Regards,

SSD

From: Ismail Djakaria <iskar@ung.ac.id>
Sent: Monday, 11 November 2024 4:49 PM
To: Sever Dragomir <sever.dragomir@ajmaa.org>
Subject: Re: Payment Proof and LaTeX File for Accepted Article

Dear Editor,

Thank you for your email. Further, we would like to know the estimated publication timeline. Additionally, if feasible, we would be grateful if the article could be scheduled for publication this month.

Thank you for your assistance, and please let us know if there is anything we can provide or complete to facilitate this process.

Best regards,

Ismail Djakaria

Payment Proof and LaTeX File for Accepted Article

Assistant Editor <assistant.editor@ajmaa.org> 12 November 2024 pukul 17.42
Balas Ke: assistant.editor@ajmaa.org
Kepada: Ismail Djakaria <iskar@ung.ac.id>, Sever Dragomir <sever.dragomir@ajmaa.org>

Dear Dr. Djakaria,

Can you please send us the LaTeX file of your paper. You have sent a docx file.

Once we receive this we can send you the Acceptance letter with expected publication dates.

Sincerely,

Camelia Crepelca
Assistant Editor
AJMAA

From: Ismail Djakaria [mailto:iskar@ung.ac.id]
Sent: Friday, 08 November, 2024 20:27
To: Sever Dragomir; assistant.editor@ajmaa.org
Subject: Payment Proof and LaTeX File for Accepted Article

[Kutipan teks disembunyikan]

Ismail Djakaria <iskar@ung.ac.id>

Payment Proof and LaTeX File for Accepted Article

Ismail Djakaria <iskar@ung.ac.id> 18 November 2024 pukul 10.21
Kepada: assistant.editor@ajmaa.org

Dear Editors,
We have attached the payment proof below for your reference. Additionally, we have attached the LaTeX file of the article as requested.

Best regards,
Ismail Djakaria

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Universitas Negeri Gorontalo UNGMail

Ismail Djakaria <iskar@ung.ac.id>

Payment Proof and LaTeX File for Accepted Article

Assistant Editor <assistant.editor@ajmaa.org> 19 November 2024 pukul 17.20
Balas Ke: assistant.editor@ajmaa.org
Kepada: Ismail Djakaria <iskar@ung.ac.id>

Dear Dr. Djakaria,

The file you have provided has been converted into LaTeX from the word doc. This file does not compile using our template and style.

Please look at the template we have included as it describes the steps you will need to take to prepare the document in our style, and the LaTeX file of the template can be used as a starting point for your own document. This template will also have samples for cross-references and bibliography requirements and citation references.

Once you have done that, we can advise on following steps.

Sincerely,

Camelia Crepelca
Assistant Editor
AJMAA

From: Ismail Djakaria [mailto:iskar@ung.ac.id]
Sent: Monday, 18 November, 2024 13:21
To: assistant.editor@ajmaa.org
Subject: Re: Payment Proof and LaTeX File for Accepted Article

[Kutipan teks disembunyikan]

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Ismail Djakaria <iskar@ung.ac.id>

Payment Proof and LaTeX File for Accepted Article

Ismail Djakaria <iskar@ung.ac.id> 20 November 2024 pukul 12.05
Kepada: assistant.editor@ajmaa.org

Dear Editors,
We have attached the formatted LaTeX file of the article as requested.

Best regards,
Ismail Djakaria

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Ismail Djakaria <iskar@ung.ac.id>

Payment Proof and LaTeX File for Accepted Article

Assistant Editor <assistant.editor@ajmaa.org> 20 November 2024 pukul 16.23
Balas Ke: assistant.editor@ajmaa.org
Kepada: Ismail Djakaria <iskar@ung.ac.id>

Dear Dr. Djakaria,

The file you have sent does not compile, does not use our journal style and you have not implemented the changes we requested regarding the cross-references, the bibliography references and many of the other style requirements that are described in detail in our template.

To clarify, we will assist with the front page matter (although again if you look at our template, you will be able to understand what needs to happen quite easily), and even bringing the paper into our style.

You however will have to implement the cross-references, the biblio references, the theorem, lemmas, proofs and so on.

I await your updated file.

Sincerely,

Camelia Crepelca
Assistant Editor
AJMAA

From: Ismail Djakaria [mailto:iskar@ung.ac.id]
Sent: Wednesday, 20 November, 2024 15:05
[Kutipan teks disembunyikan]

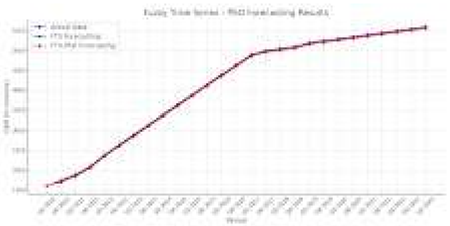
[Kutipan teks disembunyikan]

We previously emailed on 6 December 2024 regarding this manuscript but have not yet received a response. As we mentioned earlier, the revised manuscript was submitted on 21 November 2024, and given the importance of this publication for our academic objectives, we would be truly grateful if it could be considered for publication on or before 9 December 2024.

We understand and deeply respect the review and publication process, but we are reaching out again due to the urgency of this timeline. Please let us know if there are any additional steps or information required to facilitate the process.

Thank you very much for your time and attention, and I sincerely hope for your kind response at your earliest convenience.

Warm regards,
Ismail Djakaria



Fuzzy_Time_Series_PSO_Forecasting.jpg
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Ismail Djakaria <iskar@ung.ac.id>

Payment Proof and LaTeX File for Accepted Article

Ismail Djakaria <iskar@ung.ac.id>	21 November 2024 pukul 09.23
Kepada: assistant.editor@ajmaa.org

Dear Ms. Camelia Crepelca,

Thank you for your detailed feedback regarding our submission.

I have carefully reviewed the required changes and adjusted the manuscript accordingly to align with the journal's style requirements. The cross-references, bibliography, and other stylistic elements (theorems, lemmas, proofs, etc.) have been updated as per your instructions.

I have attached the revised file for your review. Please let me know if there are any further modifications needed.

Thank you for your assistance with the front page matter and for your continued guidance throughout this process.

Sincerely,
Dr. Djakaria

[Kutipan teks disembunyikan]

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Aust. J. Math. Anal. Appl.
Vol. **x** (202x), No. x, Art. x, 3 pp.
AJMAA

FULL TITLE OF THE PAPER

FIRST MIDLE NAME

Received xx Month, 202x; accepted yy Month, 202x; published zz Month, 202x.

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ABSTRACT. A brief abstract no longer than two hundred words and containing no mathematical symbols must accompany the manuscript. Bibliographic references, if necessary, should be written in full. References to theorems, equations etc. must not appear in the abstract.

Key words and phrases: Keyword1; Keyword2; Keyword3.

2020 *Mathematics Subject Classification.* Primary xxxxx, xxxxx. Secondary xxxxx, xxxxx.

ISSN (electronic): 1449-5910

The author acknowledges the grants that supported the research.

1. INTRODUCTION

Please provide a brief introduction that includes a literature review, and a description of the content sections.

2. EQUATIONS, THEOREMS, LEMMAS, PROOFS, ETC..

Please make sure you number your equations, enclose your theorems, lemmas, and other propositions, as well as the proofs using the correct LaTeX tags. Please implement and verify your cross-references for all numbered elements.

3. PAGINATION

Equations

- Equations that are too wide, and run outside of the text margins need to be broken and implemented as eqnarray or align
- Long blocks of equations need to be broken such that they do not create large blocks of whitespace on pages
- The editorial office will provide assistance and additional guidance to authors, as part of the publication process, to help improve the aesthetic of the paper, when the circumstances require it.

Images and Graphics

- The use of images, graphics and tables is encouraged to help demonstrate points, in full colour where appropriate.
- Consideration to the image quality both on screen and in print should be given by the author when making the images, and high resolution (both in px and dpi) is encouraged where possible. Specific advice can be provided by the editorial office on a case-by-case basis.
- Freedom for figure location and placement within the page is given to the author.
- Figures should be referred to, from within the text, and cross-referenced as appropriate.

4. CITATIONS AND BIBLIOGRAPHY

Please make sure you implement citations within your LaTeX file using the cite command. Please make sure you follow the journal style within your bibliography, as follows:

(1) For all entries
   - Author names are capitalized; simplest method is to use uppercase command
   - Author names use initials; for example F. M. SURNAME for FIRST MIDDLE SURNAME
   - the 'and' is not capitalized where there are multiple authors
   - commas are used to divide the different parts of the bibliography entry

(2) For journal publications
   - The title of the paper only has the first letter capitalized (unless otherwise necessary because it contains a Name or abbreviation)
   - The journal name is abbreviated as is common practice
   - The journal name is in *italics*
   - The journal volume is in **boldface**
   - The publication year is in (braces)
   - The paper publication pages are given (if known) as pp. first–last

- Additional/other information (DOI, Online link, etc...) are permitted at the end of the entry.

(3) For Books
- Book Title has First Letter Capitalized (unless it is inappropriate)
- *Book Title is Italicised*
- Book publisher is included
- Book year of publication is included, in (braces)

(4) For Conference Publications
- These should be treated as journal publications

(5) PhD Theses and Reports
- These should be treated as books

See the brief bibliography below as example.

REFERENCES

[1] J. B. DIAZ and F. T. METCALF, A complementary triangle inequality in Hilbert and Banach spaces, *Proc. Amer. Math. Soc.*, **17** (1966), pp. 88–97.

[2] S. S. DRAGOMIR, New reverses of Schwarz, triangle and Bessel inequalities in inner product spaces, *Aust. J. Math. Anal. Appl.*, **1** (2004), No. 1, Article 1, [`Online: https://ajmaa.org/cgi-bin/paper.pl?string=v1n1/nrstbiips.tex`].

[3] D. S. MITRINOVIĆ, J. E. PEČARIĆ and A. M. FINK, *Classical and New Inequalities in Analysis*, Kluwer Academic Publishers, Dordrecht, 1993.

Aust. J. Math. Anal. Appl.
Vol. **x** (202x), No. x, Art. x, 3 pp.
AJMAA

INDONESIA'S GDP FORECAST: EVIDENCE FROM FUZZY TIME SERIES MODEL USING PARTICLE SWARM OPTIMIZATION ALGORITHM

ISMAIL DJAKARIA[1*], DJIHAD WUNGGULI[2], REGINA SUGI PAKADANG[3], SRI ENDANG SALEH[4], MAMAN ABDURACHMAN DJAUHARI[5]

Received xx Month, 202x; accepted yy Month, 202x; published zz Month, 202x.

[1,2,3] Universitas Negeri Gorontalo, Department of Statistics, Gorontalo, Indonesia
[4]Universitas Negeri Gorontalo, Department of Development Economics, Gorontalo, Indonesia
[5]Indonesian Institute of Education, Jl. Terusan Pahlawan 32, Garut 44151, Indonesia.
iskar@ung.ac.id
URL: https://...

ABSTRACT. Gross Domestic Product (GDP) is a principal indicator used to measure the economic condition of a country. Indonesia's GDP growth from 2017 to 2019 was approximately 6 percent; however, it experienced a decline in 2020 and 2021, with rates of only -0.02 percent and 2.41 percent, respectively. In the process of economic development planning, a forecasting system is required to determine GDP in the future. The forecasting method employed in this research is fuzzy time series optimized using Particle Swarm Optimization (PSO), to enhance the accuracy and convergence of forecasted values. The dataset used comprises secondary data, specifically 54 sets of Indonesian GDP data spanning from the first quarter of 2010 to the second quarter of 2023. The analysis results indicate that the proposed method is better than the conventional fuzzy time series approach. The former method provides a predictive value for one period in the future with a Mean Absolute Percentage Error (MAPE) value of 4.40%. In contrast, the latter yields higher predictive values with a MAPE value of 7.93%.

Key words and phrases: forecasting model; gross domestic product; fuzzy time series; particle swarm optimization

2010 *Mathematics Subject Classification.* Primary xxxxx, xxxxx. Secondary xxxxx, xxxxx.

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1. INTRODUCTION

Gross Domestic Product (GDP) is one of the indicators used to measure the economic condition of a country. GDP includes the amount of goods and services produced by a nation's production units based on prevailing prices or constant prices. Growth with redistribution can lead to poverty and national inequality, as observed in other countries, such as the Philippines, between 2000 and 2018. Over the same 20-year period, nearly the entire territory of the country experienced growth. The growth rate experienced between 2012 and 2019 exceeded that of previous years. Economic expansion, however, has manifested unevenly across the region, with two conspicuous outliers. The National Capital Region (NCR) stands out as the most consistent economic player, maintaining a real GDP per capita of approximately 457,000 pesos (or around 8,823 USD) in 2019 [1]. One of the studies conducted in Nigeria [2] that aims to analyze or conduct studies on gross domestic income (GDI) and GDP, can reduce carbon emissions in the country. A substantial body of empirical and theoretical literature exists focusing on the impact of natural disasters, including forest fires, on GDP growth [3]. GDP serves as a prominent metric in economic accounting, commonly employed to assess the economic performance of countries and regions worldwide [4]. However, GDP lacks consideration for inclusivity and fails to furnish insights into the sustainability of economic growth [5]. The feature of providing broad consideration of the consequences of economic growth on a small (local) or global scale is needed to replace GDP in the SDG 8 indicators set to increase its coherence with the overall SDGs Agenda [6].

In planning economic development, it is essential to implement a forecast calculation system to project future GDP as a benchmark for the Indonesian economy. One applicable forecasting method is the fuzzy time series method. Through this forecasting approach, policymakers can develop and formulate more effective policies, thereby fostering a positive impact on development. This strategic use of forecasting facilitates economic development aimed at enhancing the population's welfare.

Forecasting in macroeconomics generally refers to the sequence of data related to the same statistical variable based on its chronological occurrence. The objective is to identify intrinsic relationships within the data through historical data analysis, enabling the prediction of future data points. The majority of time series modeling and forecasting involve the utilization of statistical regression models for continuous time series. Additionally, widely employed analysis models include Autoregressive Moving Average (ARMA) and Autoregressive Integrated Moving Average (ARIMA). For non-stationary time series, the initial step involves rendering it stationary through successive differencing. This process is commonly represented as a combination of white noise and moving average [7-11]. While these methods are widely recognized in economic forecasting, employing linear models, they may yield suboptimal results when applied to complex non-linear systems that aim to simulate real-life scenarios [12].

A method to address the aforementioned issue is the fuzzy time series-particle swarm optimization algorithm. Fuzzy time series are widely applied for forecasting in various cases, such as in the application of forecasting of air pollution time series data, with a new hybrid forecasting model that integrates fuzzy time series into Markov chains and C-Means clustering techniques with an optimal number of clusters [13], forecasting of weather, earthquakes, stock fluctuations and any phenomenon indexed by variables that change unexpectedly in time, given that classical time series methods cannot handle forecasting problems where time series values are linguistic terms represented by fuzzy sets [14], forecasting is therefore used as a new approach to present large time pools in a cluster, taking into account the dependencies of successive threads between times to obtain fuzzy partitions from pool observations [15, 16], forecasting subjective performance in engineering and construction management (CEM) issues, with a variety of suitable fuzzy hybrid techniques [17], forecasting coal mining production based on fuzzy-neural models [18], and in the application of fuzzy clustering to determine the distance between ordinal time series.

The proposed Fuzzy Time Series-Particle Swarm Optimization (FTS-PSO) algorithm introduces a novel approach to economic forecasting by seamlessly integrating two powerful techniques. The hybridization of Fuzzy Time Series (FTS) and Particle Swarm Optimization (PSO) leverages the strengths of each method to address critical challenges in forecasting. FTS, known for its adept handling of linguistic variables in representing qualitative information, forms the foundational component, allowing for nuanced interpretations of complex economic indicators. The PSO algorithm, operating synergistically, dynamically tunes key partitioning parameters of the FTS model during the optimization process. This adaptability not only enhances the accuracy of forecasting but also ensures the model's responsiveness to changes in the economic landscape. Importantly, FTS-PSO is explicitly designed to tackle the non-linear intricacies inherent in economic time series data, providing a more realistic representation of economic systems compared to traditional linear models. The algorithm's transparency and interpretability are preserved, allowing researchers and practitioners to trace each step of the decision-making process. Furthermore, the FTS-PSO algorithm showcases its versatility by demonstrating successful applications beyond GDP forecasting, spanning domains such as air pollution, weather, and stock fluctuations. In summary, FTS-PSO stands as an innovative and adaptive solution, contributing to the advancement of economic forecasting methodologies and offering a robust framework for addressing the complexities of diverse forecasting scenarios.

2. METHOD

The accuracy levels examined in this paper include the mean absolute percentage error (MAPE) and the Akaike information criterion (AIC). MAPE is commonly employed in modeling accuracy assessments due to its relatively straightforward interpretation of relative error. The merit of using the MAPE accuracy measure lies in its ease of comprehension and communication. It facilitates the presentation of results depicting the extent to which the estimate deviates from the actual average value, expressed in percentage terms. Consequently, MAPE assists in comparing model performance over a given timeframe, as long as the actual value does not approach zero closely. While the drawback is that MAPE can be affected by outliers or extreme values. For example, if there is an observation with a significantly large percentage of error, this can increase the accuracy value of MAPE [19-21]. Meanwhile, AIC serves as a criterion for selecting the optimal model, with the best model being characterized by the smallest AIC value.

The steps of forecasting for the fuzzy time series method are as employed by [22], [13]. This method decomposes the set of universes U into an equal number of intervals, $u_1, u_2, \ldots, u_n$. Through this step, fuzzy sets can be determined and fuzzified time series, which ultimately performs fuzzy logic relationship (FLR) modeling in fuzzification time series. The same steps are described [23].

- Describe the set of universes, U, and divide them into intervals of equal length. Assume D_{min} and D_{max} are the minimum and maximum residuals, respectively. Define $U = [D_{min} - D_1, D_{max} + D_2]$ where D_1 and D_2 are sustable positive numbers. When U is partitioned into n equal intervals
  $u_1, u_2, \ldots, u_n$, the length of the interval l, can be defined as $l = \frac{(D_{max} + D_2 - (D_{min} - D_1)}{n}$
- Determine fuzzy sets $A_1, A_2, \ldots, A_n$, as linguistic values of linguistic variables on the observed time series. Each A_i, where $i = 1, \ldots, n$ is defined by the intervals obtained in the step above and can be written as:
  $A_i = \ldots + 0/ u_i -2 + 0.5/ u_i -1 + 1/ u_i + 0.5/ u_i +1 + 0/ u_i +2 + \ldots$ (1).
  In Equation (1), the maximum membership value of A_i is contained in the interval u_i and so on.

- Calculate the forecast value for residuals based on FLR according to several methods, such as the method used by Chen, Yu, Cheng, and Lee.
- Calculate the final forecast value according to the forecast value obtained with the fuzzy model.

The steps of the calculation process are shown in the flowchart [24]. In this paper, the steps are carried out according to the following flowchart in Figure 1.

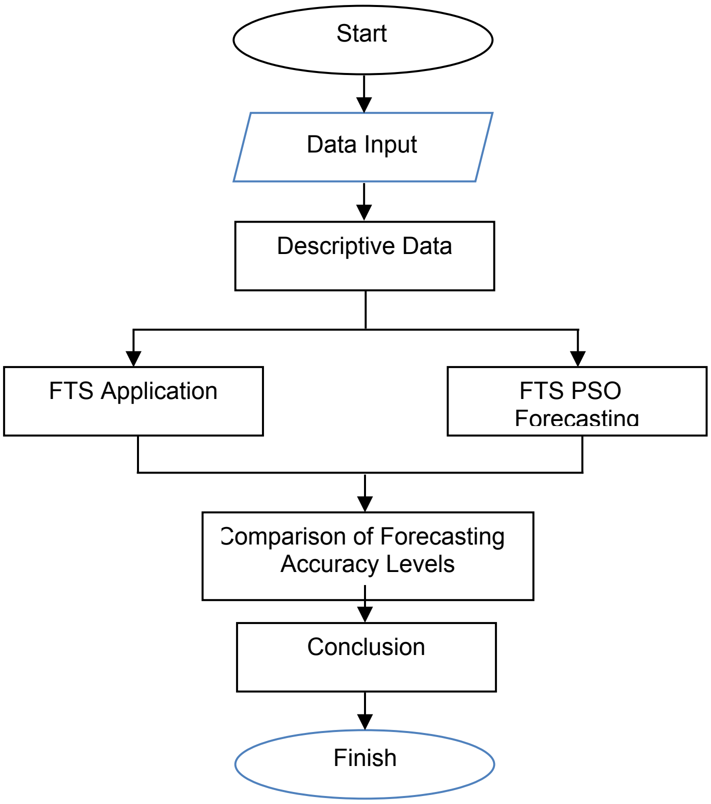


Figure 1. Flowchart of FTS PSO Forecasting Process Steps.

- Data Input: This stage involves collecting and organizing relevant data, such as historical time series data related to the phenomenon being studied. The quality and completeness of the input data play a crucial role in the accuracy of the forecasting model.

- Descriptive Data Analysis: Before applying any forecasting method, it's essential to analyze the descriptive statistics of the data. This includes measures like mean, median, standard deviation, and other statistical properties. Understanding the characteristics of the data helps in choosing appropriate modeling techniques.

- FTS Application: Fuzzy Time Series (FTS) involves capturing the uncertainty and fuzziness inherent in time series data. The application of FTS typically includes defining linguistic terms (e.g., low, medium, high), constructing fuzzy sets, and developing fuzzy rules that represent the patterns observed in the historical data.

- FTS PSO Forecasting Process Steps:

  Initialization: PSO starts with the initialization of a population of particles, each representing a potential solution. These particles are assigned random positions and velocities in the solution space.

  Objective Function Evaluation: The fuzzy time series model with PSO optimizes an objective function, which quantifies the accuracy of the forecasting model. This function takes into account the difference between the predicted values and the actual values from the historical data.

Updating Particle Positions: PSO updates the position and velocity of each particle based on its own best-known position and the best-known position of the entire swarm. This is done to search for the optimal solution in the solution space.

Fuzzy Rule Optimization: FTS, in combination with PSO, optimizes the fuzzy rules to enhance the forecasting accuracy. This step involves adjusting the parameters of the fuzzy rules to better fit the historical data patterns.

Iterative Optimization: The PSO algorithm iteratively refines the particle positions and fuzzy rule parameters to converge towards an optimal solution. This iterative process continues until a stopping criterion is met.

- Comparison of Forecasting Accuracy Levels: After applying the FTS with PSO forecasting method, the results are compared with other forecasting methods, presumably including standard FTS. This comparison is essential to assess the effectiveness and improvement achieved through the integration of Particle Swarm Optimization.
- Conclusion: The conclusion summarizes the findings, highlighting the strengths and weaknesses of the FTS with PSO forecasting approach. It may discuss the identified improvements in accuracy and provide insights into the practical implications of using this method for future predictions.
- Finish: The concluding section wraps up the study, potentially suggesting avenues for further research and application of the FTS with PSO forecasting model in different contexts. It may also discuss any limitations of the study and propose recommendations for future enhancements.

The proposed fuzzy time series model for forecasting Indonesia's GDP, incorporating a particle swarm optimization (PSO) algorithm, reveals notable limitations that impact its robustness and generalizability. Challenges arise from the model's susceptibility to partitioning parameters and the assumption of linearity in the relationship between linguistic variables and GDP within the complex economic landscape. The handling of outliers during the fuzzy logic relationship (FLR) modeling lacks explicit consideration, introducing uncertainties about the model's resilience to economic shocks. Additionally, dependence on a specific FLR method and subjective linguistic variable definitions may introduce biases, affecting forecast accuracy. Limited transparency in detailing the integration of the PSO algorithm raises concerns about the model's overall robustness.

To address these concerns, the study suggests an extension to explore alternative meta-heuristic algorithms, emphasizing the importance of a judicious selection and explicit justification. The extended methodology incorporates a broader range of forecasting models commonly used in economic prediction studies, such as autoregressive integrated moving average (ARIMA), exponential smoothing methods (e.g., Holt-Winters), and machine learning algorithms (e.g., regression models, support vector machines, or neural networks). This addition enables a more comprehensive evaluation of the performance of the fuzzy time series (FTS) and fuzzy time series with particle swarm optimization (FTSPSO) models. A rigorous evaluation strategy, employing performance metrics like mean absolute percentage error (MAPE) or root mean square error (RMSE) and statistical tests such as t-tests or ANOVA, is introduced to quantitatively assess the accuracy of each model. This enhanced methodology broadens the scope of the analysis, providing a more robust comparison and facilitating a clearer understanding of the relative strengths and weaknesses of the fuzzy time series models compared to other established forecasting techniques. The inclusion of explicit details on the alpha-cut type further contributes to a nuanced understanding of the methodology's intricacies, enhancing scholarly rigor.

3. Result and Discussion

The dataset employed in this study comprises Indonesia's quarterly Gross Domestic Product (GDP) data, measured in Billion Rupiahs at Current Market Prices by Industry. The data is sourced directly from the publication of the Central Bureau of Statistics. Specifically, the dataset spans from the first quarter of 2010 to the second quarter of 2023, covering a comprehensive timeframe for economic analysis. Table 1 provides a detailed breakdown of the quarterly GDP figures, offering a structured representation of the economic data used for the forecasting of Indonesia's GDP in this study.

Table 1. Indonesia's Quarterly GDP (Billion Rupiahs)

Index	Period	GDP Value	Index	Period	GDP Value
1	Q- I 2010	1,603,771.90	28	Q-IV 2016	3,193,903.80
2	Q-II 2010	1,704,509.90	29	Q- I 2017	3,228,172.20
3	Q-III 2010	1,786,196.60	30	Q-II 2017	3,366,787.30
4	Q-IV 2010	1,769,654.70	31	Q-III 2017	3,504,138.50
5	Q- I 2011	1,834,355.10	32	Q-IV 2017	3,490,727.70
6	Q-II 2011	1,928,233.00	33	Q- I 2018	3,510,363.10
7	Q-III 2011	2,053,745.40	34	Q-II 2018	3,686,836.40
8	Q-IV 2011	2,015,392.50	35	Q-III 2018	3,842,343.00
9	Q- I 2012	2,061,338.30	36	Q-IV 2018	3, 799,213.50
10	Q-II 2012	2,162,036.90	37	Q- I 2019	3,782,618.30
11	Q-III 2012	2,223,641.60	38	Q-II 2019	3,964,074.70
12	Q-IV 2012	2,168,687.70	39	Q-III 2019	4,067,358.00
13	Q- I 2013	2,235,288.50	40	Q-IV 2019	4,018,606.20
14	Q-II 2013	2,342,589.50	41	Q- I 2020	3,923,347.90
15	Q-III 2013	2,491,158.50	42	Q-II 2020	3,690,742.20
16	Q-IV 2013	2,477,097.50	43	Q-III 2020	3,897,851.90
17	Q- I 2014	2,506,300.20	44	Q-IV 2020	3,931,411.20
18	Q-II 2014	2,618,947.30	45	Q- I 2021	3,972,769.60
19	Q-III 2014	2,746,762.40	46	Q-II 2021	4,177,970.80
20	Q-IV 2014	2,697,695.40	47	Q-III 2021	4,327,358.00
21	Q- I 2015	2,728,180.70	48	Q-IV 2021	4,498,592.40
22	Q-II 2015	2,867,948.40	49	Q- I 2022	4,508,597.80
23	Q-III 2015	2,990,645.00	50	Q-II 2022	4,897,942.90
24	Q-IV 2015	2,939,558.70	51	Q-III 2022	5,066,994.30
25	Q- I 2016	2,929,269.00	52	Q-IV 2022	5,114,910.60
26	Q-II 2016	3,073,536.70	53	Q- I 2023	5,072,370.10
27	Q-III 2016	3,205,019.00	54	Q-II 2023	5,226,670.10

The above data plot can be shown in Figure 2.

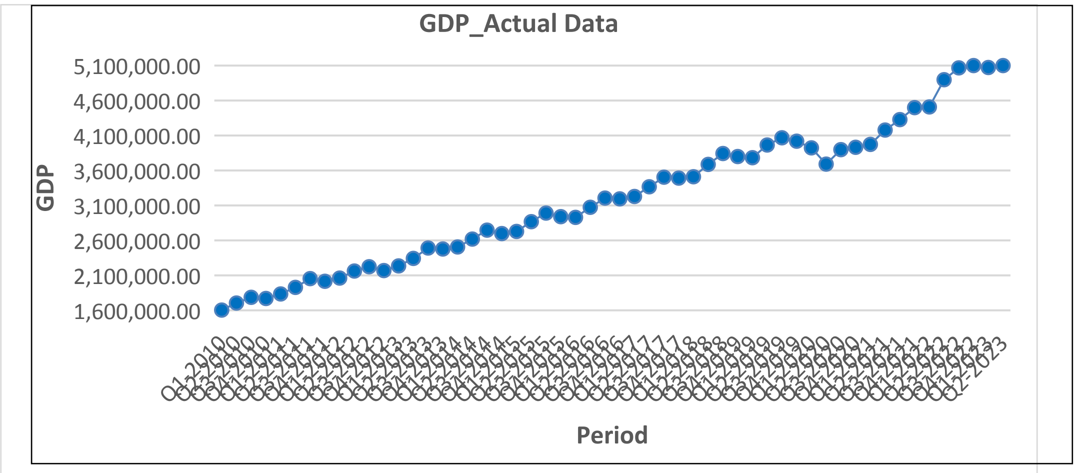


Figure 2. Indonesia's GDP Chart

Figure 2 presents a graphical representation of Indonesia's GDP data at Current Market Prices by Industry, measured in Billion Rupiahs, spanning from the first quarter of 2010 to the second quarter of 2022. The observed trend in the data pattern, as illustrated in the figure, indicates a discernible directional movement over the specified timeframe. This trend pattern provides valuable insights into the overall trajectory of Indonesia's economic output.

The minimum recorded data value occurred in the first quarter of 2010, registering at 1,603,771.90 billion Rupiahs. In contrast, the maximum value was documented in the second quarter of 2023, reaching IDR 5,226,670.10 billion. These extrema highlight the dynamic range of the GDP data, showcasing both the lowest and highest values within the given period.

The recognition of a discernible trend in the GDP data pattern serves as a rationale for considering the application of fuzzy time series for forecasting. The distinct fluctuations and directional movements in the data offer a foundation for exploring the potential of fuzzy time series methodology in capturing and predicting the intricate dynamics of Indonesia's economic output.

Fuzzy Time Series Analysis

The set of universes is derived from historical data through the establishment of minimum and maximum data bounds for the universes. In this context, specific parameters are defined to shape the universes: $d_1 = 0, d_2 = 100$, $D_{min} = 1{,}603{,}771.90$, and $D_{max} = 5{,}226{,}670.10$. These parameters lead to the formation of the universe set, denoted as $U = [1{,}603{,}771.90; 5{,}226{,}670.10]$.
To determine the number of intervals, K, the formula $K = 1 + 3.3 \cdot \log(54)$ is utilized, resulting in

K ≈ 6.7168, rounded to 7. Subsequently, fuzzy sets are derived by dividing the sum of intervals within U into K equal parts. Table 2 provides a clear representation of these fuzzy sets, delineating the intervals and corresponding linguistic values obtained from the historical data.

This systematic approach ensures a transparent explanation of the process involved in forming the set of universes, specifying the parameters used and how the intervals are determined. The subsequent representation in Table 2 further enhances the clarity of the derived fuzzy sets, establishing a foundation for the subsequent steps in the fuzzy time series modeling methodology.

Table 2. Fuzzy set

Interval	Lower Bound	Upper Bound	Middle Value	Fuzzy Set
U_1	1,603,771.90	2,121,343.07	1,862,557.49	A_1
U_2	2,121,343.07	2,638,914.24	2,380,128.66	A_2
U_3	2,638,914.24	3,156,485.41	2,897,699.83	A_3
U_4	3,156,485.41	3,674,056.59	3,415,271.00	A_4
U_5	3,674,056.59	4,191,627.76	3,932,842.17	A_5
U_6	4,191,627.76	4,709,198.93	4,450,413.34	A_6
U_7	4,709,198.93	5,226,770.10	4,967,984.51	A_7

After conducting a fuzzy time series analysis based on intervals, the set of speech universes and fuzzy sets obtained forecasting results, as shown in Table 3.

Table 3. Results of Indonesia's GDP Forecasting (Billion Rupiahs)

Period	GDP Value	Forecasting	Period	GDP Value	Forecasting
Q- I 2010	1,603,771.90	NA	Q-IV 2016	3,193,903.80	3,489,209.74
Q-II 2010	1,704,509.90	1,920,065.39	Q- I 2017	3,228,172.20	3,489,209.74
Q-III 2010	1,786,196.60	1,920,065.39	Q-II 2017	3,366,787.30	3,489,209.74
Q-IV 2010	1,769,654.70	1,920,065.39	Q-III 2017	3,504,138.50	3,489,209.74
Q- I 2011	1,834,355.10	1,920,065.39	Q-IV 2017	3,490,727.70	3,489,209.74
Q-II 2011	1,928,233.00	1,920,065.39	Q- I 2018	3,510,363.10	3,489,209.74
Q-III 2011	2,053,745.40	1,920,065.39	Q-II 2018	3,686,836.40	3,747,995.32
Q-IV 2011	2,015,392.50	1,920,065.39	Q-III 2018	3,842,343.00	3,972,655.34
Q- I 2012	2,061,338.30	1,920,065.39	Q-IV 2018	3,799,213.50	3,972,655.34
Q-II 2012	2,162,036.90	2,178,850.98	Q- I 2019	3,782,618.30	3,972,655.34
Q-III 2012	2,223,641.60	2,437,636.57	Q-II 2019	3,964,074.70	3,972,655.34
Q-IV 2012	2,168,687.70	2,437,636.57	Q-III 2019	4,067,358.00	3,972,655.34
Q- I 2013	2,235,288.50	2,437,636.57	Q-IV 2019	4,018,606.20	3,972,655.34
Q-II 2013	2,342,589.50	2,437,636.57	Q- I 2020	3,923,347.90	3,972,655.34
Q-III 2013	2,491,158.50	2,437,636.57	Q-II 2020	3,690,742.20	3,972,655.34
Q-IV 2013	2,477,097.50	2,437,636.57	Q-III 2020	3,897,851.90	3,972,655.34
Q- I 2014	2,506,300.20	2,437,636.57	Q-IV 2020	3,931,411.20	3,972,655.34
Q-II 2014	2,618,947.30	2,437,636.57	Q- I 2021	3,972,769.60	3,972,655.34
Q-III 2014	2,746,762.40	2,696,422.15	Q-II 2021	4,177,970.80	3,972,655.34

Q-IV 2014	2,697,695.40	2,962,396.23	Q-III 2021	4,327,358.00	4,231,440.92
Q- I 2015	2,728,180.70	2,962,396.23	Q-IV 2021	4,498,592.40	4,622,937.07
Q-II 2015	2,867,948.40	2,962,396.23	Q- I 2022	4,508,597.80	4,622,937.07
Q-III 2015	2,990,645.00	2,962,396.23	Q-II 2022	4,897,942.90	4,881,722.65
Q-IV 2015	2,939,558.70	2,962,396.23	Q-III 2022	5,066,994.30	4,967,984.51
Q- I 2016	2,929,269.00	2,962,396.23	Q-IV 2022	5,114,910.60	4,967,984.51
Q-II 2016	3,073,536.70	2,962,396.23	Q- I 2023	5,072,370.10	4,967,984.51
Q-III 2016	3,205,019.00	3,221,181.81	Q-II 2023	5,226,670.10	4,967,984.51

Referring to Table 3, the forecasted value for Indonesia's GDP in the upcoming period is projected to be 4,967,984.51 billion Rupiahs. This forecast is generated through the application of the fuzzy time series model, incorporating historical data and linguistic variables. The forecasted value provides an estimation of the economic output for the forthcoming period based on the established patterns and relationships identified in the historical GDP data.

Additionally, the Mean Absolute Percentage Error (MAPE) is calculated as 7.93%. MAPE is a measure of the accuracy of the forecasting model, representing the average percentage difference between the predicted and actual values. In this context, a MAPE of 7.93% suggests that, on average, the forecasted GDP values deviate by approximately 7.93% from the actual observed values. Lower MAPE values generally indicate a higher level of accuracy in the forecasting model.

Interpreting these results, the forecasted GDP value provides insight into the expected economic performance for the specified period, while the MAPE metric offers a quantitative measure of the accuracy of the forecasting model. A lower MAPE value indicates a more accurate forecast, implying that the fuzzy time series model has demonstrated a relatively precise ability to capture and predict the patterns in Indonesia's GDP data. However, it's essential to consider the specific context and requirements of the forecasting application when evaluating the adequacy of the model's performance.

Fuzzy Time Series using Particle Swam Optimization

Initial Parameter

The PSO parameters include the number of particles, commonly chosen within the range of multiples of 5 to 100, the number of iterations, the weight of iterations (w) starting from 0.5 to 1, and a combination of c1 and c2, subject to the condition that c1 + c2 ≤ 4. This paper adopts the PSO parameters as outlined in Table 4.

Table 4. PSO Parameter

No.	PSO Parameter	Value
1	Number of iteration	50
2	Number of particles	10
3	Weight of iteration	0.5
4	c_1	1.5
5	c_2	1.5
6	r_1	0.3
7	r_2	0.2

Position and initial velocity of particles

The initial velocity of each particle is assumed to be zero. The number of dimensions for the particles is determined by subtracting one from the total number of particles, i.e., 7 – 1 = 6 dimensions. The initial velocities of the particles are presented in Table 5.

Table 5. The Initial Velocity of The Particle

No.	d_1	d_2	d_3	d_4	d_5	d_6
1	0	0	0	0	0	0
2	0	0	0	0	0	0

3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0

The initial positions of each particle in the particle swarm optimization (PSO) algorithm are determined through a random generation process. The generated positions are constrained within the historical data bounds, specifically ranging from 1,603,771.90 to 5,226,770.10. It's worth noting that the values of both lower and upper bounds (1,603,771.90 and 5,226,770.10, respectively) are fixed and not included in the randomly generated positions.

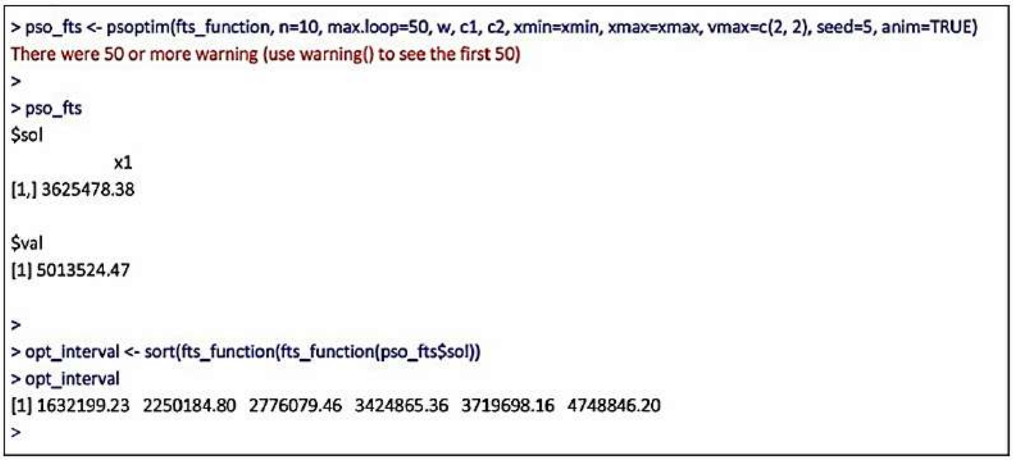
Table 6 presents a detailed overview of these initial positions for each particle. The values listed in the table represent the randomly generated positions within the specified data bounds. The initial positions play a crucial role in initiating the PSO algorithm, influencing how particles explore the solution space in search of optimal parameter values for the fuzzy time series model.

Table 6. The Initial Position of The Particle

No.	d_1	d_2	d_3	d_4	d_5	d_6
1	1,776,329.23	2,263,802.21	3,073,536.70	4,007,008.01	4,167,338.76	4,072,169.66
2	1,776,329.23	2,117,436.47	3,105,219.27	4,008,606.11	4,018,555.28	4,117,270.83
3	1,821,067.72	2,078,418.32	3,187,813.82	4,023,347.91	3,923,347.14	4,027,458.72
4	1,869,224.63	2,272,514.26	3,238,273.42	3,690,742.24	3,890,732.21	4,328,512.42
5	1,831,747.26	2,723,541.26	3,476,787.64	3,897,851.97	4,067,358.14	4,408,398.63
6	1,977,333.08	2,216,768.82	3,476,787.64	3,978,611.23	4,218,006.32	4,897,942.61
7	1,869,224.63	2,352,344.53	3,476,787.64	4,009,678.03	4,013,447.33	5,102,124.13
8	1,879,114.12	2,352,344.53	3,523,363.12	4,118,504.22	4,190,732.29	5,111,211.64
9	1,872,671.12	2,352,344.53	3,523,363.12	4,254,348.54	4,767,458.44	5,272,381.41
10	1,946,373.10	2,486,123.61	3,847,443.37	4,093,642.25	4,518,706.18	5,204,113.14

Fuzzy time series PSO

Optimum results of wide fuzzy time series intervals with PSO with the help of *Rstudio software.*



```
> pso_fts <- psoptim(fts_function, n=10, max.loop=50, w, c1, c2, xmin=xmin, xmax=xmax, vmax=c(2, 2), seed=5, anim=TRUE)
There were 50 or more warning (use warning() to see the first 50)
>
> pso_fts
$sol
            x1
[1,] 3625478.38

$val
[1] 5013524.47

>
> opt_interval <- sort(fts_function(fts_function(pso_fts$sol))
> opt_interval
[1] 1632199.23  2250184.80  2776079.46  3424865.36  3719698.16  4748846.20
>
```

Figure 3. Output Interval PSO

In Figure 3, the Particle Swarm Optimization (PSO) algorithm yields an optimum solution for the fuzzy time series model, resulting in a forecasted GDP value of 3,625,478.38. This optimal solution corresponds to a fitness value of 5,013,524.47. Additionally, the PSO algorithm identifies an optimal set of intervals for the fuzzy time series model, which is determined as follows: 1,632,199.23; 2,250,184.80; 2,776,079.46; 3,424,865.36; 3,719,698.16; 4,748,846.20.

These optimal intervals are then used to form fuzzy sets denoted as $A_1, A_2, ..., A_7$. Each fuzzy set interval is defined based on the identified optimum values and is represented as $A_1 = (D_{min} - d_1, x_1)$, $A_2 = (x_1, x_2)$, ..., $A_7 = (x_6, D_{max} + d_2)$, where x_1 to x_6 is the determined interval boundaries. The resulting fuzzy sets, along with their respective intervals, are organized and presented in Table 7.

Table 7. Fuzzy Set Interval

Fuzzy set	Lower Bound	Upper Bound	Middle Value
A_1	1,603,771.90	1,632,199.23	1,617,985.57
A_2	1,632,199.23	2,250,184.80	1,941,192.02
A_3	2,250,184.80	2,776,079.46	2,513,132.13
A_4	2,776,079.46	3,424,865.36	3,100,472.41
A_5	3,424,865.36	3,719,698.16	3,572,281.76
A_6	3,719,698.16	4,748,846.20	4,234,272.18
A_7	4,748,846.20	5,226,670.10	4,987,758.15

After conducting fuzzy time series analysis based on fuzzy set intervals PSO forecasting results are shown in Table 8.

Table 8. Fuzzy Time Series_PSO Forecasting Results

Period	GDP Value	Forecasting	Period	GDP Value	Forecasting
Q- I 2010	1,603,771.90	NA	Q-IV 2016	3,193,903.80	3,221,181.81
Q-II 2010	1,704,509.90	1,812,287.65	Q- I 2017	3,228,172.20	3,221,181.81
Q-III 2010	1,786,196.60	2,246,097.50	Q-II 2017	3,366,787.30	3,221,181.81
Q-IV 2010	1,769,654.70	2,246,097.50	Q-III 2017	3,504,138.50	3,221,181.81
Q- I 2011	1,834,355.10	2,246,097.50	Q-IV 2017	3,490,727.70	3,982,655.34
Q-II 2011	1,928,233.00	2,246,097.50	Q- I 2018	3,510,363.10	3,982,655.34
Q-III 2011	2,053,745.40	2,246,097.50	Q-II 2018	3,686,836.40	3,982,655.34
Q-IV 2011	2,015,392.50	2,246,097.50	Q-III 2018	3,842,343.00	3,982,655.34
Q- I 2012	2,061,338.30	2,246,097.50	Q-IV 2018	3,799,213.50	3,982,655.34
Q-II 2012	2,162,036.90	2,246,097.50	Q- I 2019	3,782,618.30	3,982,655.34
Q-III 2012	2,223,641.60	2,246,097.50	Q-II 2019	3,964,074.70	3,982,655.34
Q-IV 2012	2,168,687.70	2,246,097.50	Q-III 2019	4,067,358.00	3,982,655.34
Q- I 2013	2,235,288.50	2,246,097.50	Q-IV 2019	4,018,606.20	3,982,655.34
Q-II 2013	2,342,589.50	2,246,097.50	Q- I 2020	3,923,347.90	4,444,340.92
Q-III 2013	2,491,158.50	2,246,097.50	Q-II 2020	3,690,742.20	4,444,340.92
Q-IV 2013	2,477,097.50	2,246,097.50	Q-III 2020	3,897,851.90	4,444,340.92
Q- I 2014	2,506,300.20	2,772,645.24	Q-IV 2020	3,931,411.20	4,444,340.92
Q-II 2014	2,618,947.30	2,772,645.24	Q- I 2021	3,972,769.60	4,444,340.92
Q-III 2014	2,746,762.40	2,772,645.24	Q-II 2021	4,177,970.80	4,444,340.92
Q-IV 2014	2,697,695.40	2,772,645.24	Q-III 2021	4,327,358.00	4,444,340.92
Q- I 2015	2,728,180.70	2,772,645.24	Q-IV 2021	4,498,592.40	4,743,338.12
Q-II 2015	2,867,948.40	2,772,645.24	Q- I 2022	4,508,597.80	4,743,338.12
Q-III 2015	2,990,645.00	2,772,645.24	Q-II 2022	4,897,942.90	4,743,338.12
Q-IV 2015	2,939,558.70	2,772,645.24	Q-III 2022	5,066,994.30	5,116,852.62
Q- I 2016	2,929,269.00	2,772,645.24	Q-IV 2022	5,114,910.60	5,116,852.62
Q-II 2016	3,073,536.70	3,221,181.81	Q- I 2023	5,072,370.10	5,116,852.62
Q-III 2016	3,205,019.00	3,221,181.81	Q-II 2023	5,226,670.10	5,116,852.62

Referring to Table 8, the forecasted value for Indonesia's GDP in the upcoming period (Q-III 2023) is projected to be 5,116,852.62 billion Rupiahs. This forecast is derived from the fuzzy time series model, which incorporates the optimized parameters obtained through the Particle Swarm Optimization (PSO) algorithm. The forecasted value represents an estimate of the economic output for the specified future period, based on the identified patterns and linguistic representations in the historical GDP data.

The fuzzy time series model, with the optimized intervals determined by PSO, contributes to a more accurate and refined forecasting process. The forecasted GDP value of 5,116,852.62 billion Rupiahs provides valuable insights for decision-makers, analysts, and stakeholders, aiding in anticipating and planning for the economic performance of Indonesia in Q-III 2023. This output represents the culmination of the fuzzy time series modeling and optimization efforts, offering a quantified projection for the specified period.

Comparison of fuzzy time series and fuzzy time series PSOs

The comparison of the accuracy of fuzzy time series and fuzzy time series PSO forecasting are the AIC and MAPE. The results of AIC and MAPE values can be seen in Table 9.

Table 9. Comparison of Forecasting Results

Method	AIC	MAPE
Fuzzy time series	2773.32	7.93%
Fuzzy time series PSO	2137.21	4.40%

Based on the findings in Table 9, it is evident that the fuzzy time series method combined with PSO outperforms the conventional fuzzy time series, as indicated by its smaller error value (MAPE). A representation of the accuracy comparison between fuzzy time series and fuzzy time series forecasting with PSO is presented in Figure 4.

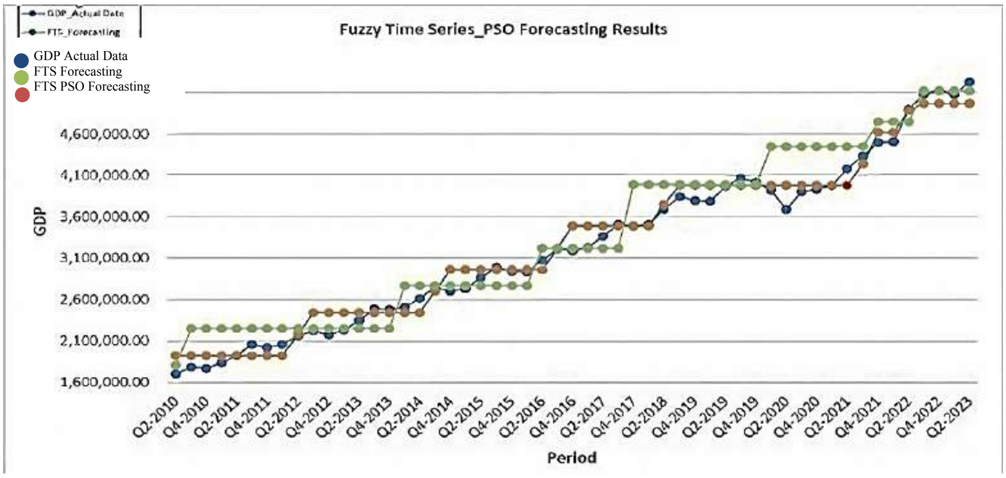


Figure 4. Fuzzy time series PSO Forecasting of Indonesia's GDP

Figure 4 illustrates that the integration of the Particle Swarm Optimization (PSO) algorithm with the fuzzy time series method leads to an enhanced performance compared to the standard fuzzy time series alone. The plot demonstrates a closer alignment between the forecasted values obtained through the fuzzy time series method with PSO optimization and the actual Indonesia's GDP data. This closer alignment signifies that the optimized parameters, obtained through the PSO algorithm, contribute to a more accurate representation of the underlying patterns in the GDP data.

The overall conclusion drawn from this observation is that the combined approach, incorporating PSO for parameter optimization, improves the forecasting accuracy of the fuzzy time series model. The enhanced alignment between the forecasted values and the actual data suggests that the optimized parameters allow the model to capture and represent the complex dynamics of Indonesia's GDP more effectively. This outcome reinforces the value of meta-heuristic optimization techniques, such as PSO, in refining the fuzzy time series methodology for robust economic forecasting.

In summary, the results and discussions affirm that the integration of PSO with the fuzzy time series model is a promising approach for improving the accuracy of GDP forecasts. This finding holds significance for practitioners, policymakers, and researchers involved in economic forecasting, providing insights into effective methodologies for capturing and predicting the intricate dynamics of Indonesia's economic landscape.

4. CONCLUSION

Based on the comprehensive results and discussions, a robust conclusion can be drawn regarding the fuzzy time series predictions for Indonesia's GDP using particle swarm optimization (FTS-PSO). The model, optimized through the particle swarm optimization algorithm, successfully identified seven intervals that span the dynamic range from the lower limit of 1,603,771.90 to the upper limit of 5,226,770.10 in the historical data. The forecasted GDP value using FTS-PSO is 5,116,852.62 billion Rupiahs, with a remarkably low Mean Absolute Percentage Error (MAPE) value of 4.40%.

In comparison, the forecasting results for Indonesia's GDP using the standard fuzzy time series alone yielded a predicted value of 4,967,984.51 billion Rupiahs, accompanied by a higher MAPE value of 7.93%. This stark difference in MAPE values underscores the superiority of the FTS-PSO approach, as it demonstrates a significantly lower percentage deviation between the predicted and actual values.

The original theoretical and technical contributions of this paper lie in the successful integration of particle swarm optimization with fuzzy time series for GDP forecasting. The FTS-PSO model outperforms the standard fuzzy time series model, providing a more accurate representation of Indonesia's economic dynamics. This research contributes to the field by showcasing the effectiveness of meta-heuristic optimization, particularly PSO, in refining fuzzy time series models for enhanced accuracy in economic forecasting. The identification of optimized intervals and the subsequent reduction in MAPE value highlight the practical implications of this approach for policymakers, analysts, and researchers engaged in economic prediction. Overall, this paper adds valuable insights to the methodology of economic forecasting, emphasizing the potential of combining fuzzy time series with meta-heuristic algorithms for superior predictive performance.

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INDONESIA'S GDP FORECAST: EVIDENCE FROM FUZZY TIME SERIES MODEL USING PARTICLE SWARM OPTIMIZATION ALGORITHM

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ABSTRACT. Gross Domestic Product (GDP) is a principal indicator used to measure the economic condition of a country. Indonesia's GDP growth from 2017 to 2019 was approximately 6 percent; however, it experienced a decline in 2020 and 2021, with rates of only -0.02 percent and 2.41 percent, respectively. In the process of economic development planning, a forecasting system is required to determine GDP in the future. The forecasting method employed in this research is fuzzy time series optimized using Particle Swarm Optimization (PSO), to enhance the accuracy and convergence of forecasted values. The dataset used comprises secondary data, specifically 54 sets of Indonesian GDP data spanning from the first quarter of 2010 to the second quarter of 2023. The analysis results indicate that the proposed method is better than the conventional fuzzy time series approach. The former method provides a predictive value for one period in the future with a Mean Absolute Percentage Error (MAPE) value of 4.40%. In contrast, the latter yields higher predictive values with a MAPE value of 7.93%.

Key words and phrases: Forecasting model; Gross domestic product; Fuzzy time series; Particle swarm optimization.

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1. INTRODUCTION

Gross Domestic Product (GDP) is one of the indicators used to measure the economic condition of a country. GDP includes the amount of goods and services produced by a nation's production units based on prevailing prices or constant prices. Growth with redistribution can lead to poverty and national inequality, as observed in other countries, such as the Philippines, between 2000 and 2018. Over the same 20-year period, nearly the entire territory of the country experienced growth. The growth rate experienced between 2012 and 2019 exceeded that of previous years. Economic expansion, however, has manifested unevenly across the region, with two conspicuous outliers. The National Capital Region (NCR) stands out as the most consistent economic player, maintaining a real GDP per capita of approximately 457,000 pesos (or around 8,823 USD) in 2019 [1]. One of the studies conducted in Nigeria [2] that aims to analyze or conduct studies on gross domestic income (GDI) and GDP, can reduce carbon emissions in the country. A substantial body of empirical and theoretical literature exists focusing on the impact of natural disasters, including forest fires, on GDP growth [3]. GDP serves as a prominent metric in economic accounting, commonly employed to assess the economic performance of countries and regions worldwide [4]. However, GDP lacks consideration for inclusivity and fails to furnish insights into the sustainability of economic growth [5]. The feature of providing broad consideration of the consequences of economic growth on a small (local) or global scale is needed to replace GDP in the SDG 8 indicators set to increase its coherence with the overall SDGs Agenda [6].

In planning economic development, it is essential to implement a forecast calculation system to project future GDP as a benchmark for the Indonesian economy. One applicable forecasting method is the fuzzy time series method. Through this forecasting approach, policymakers can develop and formulate more effective policies, thereby fostering a positive impact on development. This strategic use of forecasting facilitates economic development aimed at enhancing the population's welfare.

Forecasting in macroeconomics generally refers to the sequence of data related to the same statistical variable based on its chronological occurrence. The objective is to identify intrinsic relationships within the data through historical data analysis, enabling the prediction of future data points. The majority of time series modeling and forecasting involve the utilization of statistical regression models for continuous time series. Additionally, widely employed analysis models include Autoregressive Moving Average (ARMA) and Autoregressive Integrated Moving Average (ARIMA). For non-stationary time series, the initial step involves rendering it stationary through successive differencing. This process is commonly represented as a combination of white noise and moving average [7]-[11]. While these methods are widely recognized in economic forecasting, employing linear models, they may yield suboptimal results when applied to complex non-linear systems that aim to simulate real-life scenarios [12].

A method to address the aforementioned issue is the fuzzy time series-particle swarm optimization algorithm. Fuzzy time series are widely applied for forecasting in various cases, such as in the application of forecasting of air pollution time series data, with a new hybrid forecasting model that integrates fuzzy time series into Markov chains and C-Means clustering techniques with an optimal number of clusters [13], forecasting of weather, earthquakes, stock fluctuations and any phenomenon indexed by variables that change unexpectedly in time, given that classical time series methods cannot handle forecasting problems where time series values are linguistic terms represented by fuzzy sets [14], forecasting is therefore used as a new approach to present large time pools in a cluster, taking into account the dependencies of successive threads between times to obtain fuzzy partitions from pool observations [15], [16], forecasting subjective performance in engineering and construction management (CEM) issues, with a variety of suitable fuzzy hybrid techniques [17], forecasting coal mining production based on fuzzy-neural models [18], and in the application of fuzzy clustering to determine the distance between ordinal time series.

The proposed Fuzzy Time Series-Particle Swarm Optimization (FTS-PSO) algorithm introduces a novel approach to economic forecasting by seamlessly integrating two powerful techniques. The hybridization of Fuzzy Time Series (FTS) and Particle Swarm Optimization (PSO) leverages the strengths of each method to address critical challenges in forecasting. FTS, known for its adept handling of linguistic variables in representing qualitative information, forms the foundational component, allowing for nuanced interpretations of complex economic indicators. The PSO algorithm, operating synergistically, dynamically tunes key partitioning parameters of the FTS model during the optimization process. This adaptability not only enhances the accuracy of forecasting but also ensures the model's responsiveness to changes in the economic landscape. Importantly, FTS-PSO is explicitly designed to tackle the non-linear intricacies inherent in economic time series data, providing a more realistic representation of economic systems compared to traditional linear models. The algorithm's transparency and interpretability are preserved, allowing researchers and practitioners to trace each step of the decision-making process. Furthermore, the FTS-PSO algorithm showcases its versatility by demonstrating successful applications beyond GDP forecasting, spanning domains such as air pollution, weather, and stock fluctuations. In summary, FTS-PSO stands as an innovative and adaptive solution, contributing to the advancement of economic forecasting methodologies and offering a robust framework for addressing the complexities of diverse forecasting scenarios.

2. METHOD

The accuracy levels examined in this paper include the mean absolute percentage error (MAPE) and the Akaike information criterion (AIC). MAPE is commonly employed in modeling accuracy assessments due to its relatively straightforward interpretation of relative error. The merit of using the MAPE accuracy measure lies in its ease of comprehension and communication. It facilitates the presentation of results depicting the extent to which the estimate deviates from the actual average value, expressed in percentage terms. Consequently, MAPE assists in comparing model performance over a given timeframe, as long as the actual value does not approach zero closely. While the drawback is that MAPE can be affected by outliers or extreme values. For example, if there is an observation with a significantly large percentage of error, this can increase the accuracy value of MAPE [19]-[21]. Meanwhile, AIC serves as a criterion for selecting the optimal model, with the best model being characterized by the smallest AIC value.

The steps of forecasting for the fuzzy time series method are as employed by [22], [13]. This method decomposes the set of universes U into an equal number of intervals, u_1, u_2, …, u_n. Through this step, fuzzy sets can be determined and fuzzified time series, which ultimately performs fuzzy logic relationship (FLR) modeling in fuzzification time series. The same steps are described [23].

- Describe the set of universes, U, and divide them into intervals of equal length. Assume D_{min} and D_{max} are the minimum and maximum residuals, respectively. Define $U = [D_{min} - D_1, D_{max} + D_2]$ where D_1 and D_2 are sustable positive numbers. When U is partitioned into n equal intervals

$u_1, u_2, \ldots, u_n$, the length of the interval l, can be defined as $l = (D_{max} + D_2 - (D_{min} - D_1)$
n

- Determine fuzzy sets $A_1, A_2, \ldots, A_n$, as linguistic values of linguistic variables on the observed time series. Each A_i, where $i = 1, \ldots, n$ is defined by the intervals obtained in the step above and can be written as:

$A_i = \ldots + 0/ u_i -2 + 0.5/ u_i -1 + 1/ u_i + 0.5/ u_i +1 + 0/ u_i +2 + \ldots$ (1).

In Equation (1), the maximum membership value of A_i is contained in the interval u_i and so on.

- Calculate the forecast value for residuals based on FLR according to several methods, such as the method used by Chen, Yu, Cheng, and Lee.
- Calculate the final forecast value according to the forecast value obtained with the fuzzy model.

The steps of the calculation process are shown in the flowchart [24]. In this paper, the steps are carried out according to the following flowchart in Figure 1.

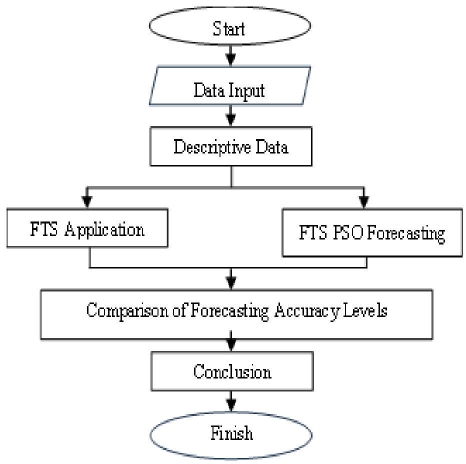

Figure 1: Flowchart of FTS PSO Forecasting Process Steps.

- Data Input: This stage involves collecting and organizing relevant data, such as historical time series data related to the phenomenon being studied. The quality and completeness of the input data play a crucial role in the accuracy of the forecasting model.
- Descriptive Data Analysis: Before applying any forecasting method, it's essential to analyze the descriptive statistics of the data. This includes measures like mean, median, standard deviation, and other statistical properties. Understanding the characteristics of the data helps in choosing appropriate modeling techniques.
- FTS Application: Fuzzy Time Series (FTS) involves capturing the uncertainty and fuzziness inherent in time series data. The application of FTS typically includes defining linguistic terms (e.g., low, medium, high), constructing fuzzy sets, and developing fuzzy rules that represent the patterns observed in the historical data.
- FTS PSO Forecasting Process Steps:

Initialization: PSO starts with the initialization of a population of particles, each representing a potential solution. These particles are assigned random positions and velocities in the solution space.

Objective Function Evaluation: The fuzzy time series model with PSO optimizes an objective function, which quantifies the accuracy of the forecasting model. This function takes into account the difference between the predicted values and the actual values from the historical data.

Updating Particle Positions: PSO updates the position and velocity of each particle based on its own best-known position and the best-known position of the entire swarm. This is done to search for the optimal solution in the solution space.

Fuzzy Rule Optimization: FTS, in combination with PSO, optimizes the fuzzy rules to enhance the forecasting accuracy. This step involves adjusting the parameters of the fuzzy rules to better fit the historical data patterns.

Iterative Optimization: The PSO algorithm iteratively refines the particle positions and fuzzy rule parameters to converge towards an optimal solution. This iterative process continues until a stopping criterion is met.

- Comparison of Forecasting Accuracy Levels: After applying the FTS with PSO forecasting method, the results are compared with other forecasting methods, presumably including standard FTS. This comparison is essential to assess the effectiveness and improvement achieved through the integration of Particle Swarm Optimization.
- Conclusion: The conclusion summarizes the findings, highlighting the strengths and weaknesses of the FTS with PSO forecasting approach. It may discuss the identified improvements in accuracy and provide insights into the practical implications of using this method for future predictions.
- Finish: The concluding section wraps up the study, potentially suggesting avenues for further research and application of the FTS with PSO forecasting model in different contexts. It may also discuss any limitations of the study and propose recommendations for future enhancements.

The proposed fuzzy time series model for forecasting Indonesia's GDP, incorporating a particle swarm optimization (PSO) algorithm, reveals notable limitations that impact its robustness and generalizability. Challenges arise from the model's susceptibility to partitioning parameters and the assumption of linearity in the relationship between linguistic variables and GDP within the complex economic landscape. The handling of outliers during the fuzzy logic relationship (FLR) modeling lacks explicit consideration, introducing uncertainties about the model's resilience to economic shocks. Additionally, dependence on a specific FLR method and subjective linguistic variable definitions may introduce biases, affecting forecast accuracy. Limited transparency in detailing the integration of the PSO algorithm raises concerns about the model's overall robustness.

To address these concerns, the study suggests an extension to explore alternative metaheuristic algorithms, emphasizing the importance of a judicious selection and explicit justification. The extended methodology incorporates a broader range of forecasting models commonly used in economic prediction studies, such as autoregressive integrated moving average (ARIMA), exponential smoothing methods (e.g., Holt-Winters), and machine learning algorithms (e.g., regression models, support vector machines, or neural networks). This addition enables a more comprehensive evaluation of the performance of the fuzzy time series (FTS) and fuzzy time series with particle swarm optimization (FTSPSO) models. A rigorous evaluation strategy, employing performance metrics like mean absolute percentage error (MAPE) or root mean square error (RMSE) and statistical tests such as t-tests or ANOVA, is introduced to quantitatively assess the accuracy of each model. This enhanced methodology broadens the scope of the analysis, providing a more robust comparison and facilitating a clearer understanding of the relative strengths and weaknesses of the fuzzy time series models compared to other established forecasting techniques. The inclusion of explicit details on the alpha-cut type further contributes to a nuanced understanding of the methodology's intricacies, enhancing scholarly rigor.

3. Result and Discussion

The dataset employed in this study comprises Indonesia's quarterly Gross Domestic Product (GDP) data, measured in Billion Rupiahs at Current Market Prices by Industry. The data is sourced directly from the publication of the Central Bureau of Statistics. Specifically, the dataset spans from the first quarter of 2010 to the second quarter of 2023, covering a comprehensive timeframe for economic analysis. Table 1 provides a detailed breakdown of the quarterly GDP figures, offering a structured representation of the economic data used for the forecasting of Indonesia's GDP in this study.

Table 1. Indonesia's Quarterly GDP (Billion Rupiahs)

Index	Period	GDP Value	Index	Period	GDP Value
1	Q- I 2010	1,603,771.90	28	Q-IV 2016	3,193,903.80
2	Q-II 2010	1,704,509.90	29	Q- I 2017	3,228,172.20
3	Q-III 2010	1,786,196.60	30	Q-II 2017	3,366,787.30
4	Q-IV 2010	1,769,654.70	31	Q-III 2017	3,504,138.50
5	Q- I 2011	1,834,355.10	32	Q-IV 2017	3,490,727.70
6	Q-II 2011	1,928,233.00	33	Q- I 2018	3,510,363.10
7	Q-III 2011	2,053,745.40	34	Q-II 2018	3,686,836.40
8	Q-IV 2011	2,015,392.50	35	Q-III 2018	3,842,343.00
9	Q- I 2012	2,061,338.30	36	Q-IV 2018	3,799,213.50
10	Q-II 2012	2,162,036.90	37	Q- I 2019	3,782,618.30
11	Q-III 2012	2,223,641.60	38	Q-II 2019	3,964,074.70
12	Q-IV 2012	2,168,687.70	39	Q-III 2019	4,067,358.00
13	Q- I 2013	2,235,288.50	40	Q-IV 2019	4,018,606.20
14	Q-II 2013	2,342,589.50	41	Q- I 2020	3,923,347.90
15	Q-III 2013	2,491,158.50	42	Q-II 2020	3,690,742.20
16	Q-IV 2013	2,477,097.50	43	Q-III 2020	3,897,851.90
17	Q- I 2014	2,506,300.20	44	Q-IV 2020	3,931,411.20
18	Q-II 2014	2,618,947.30	45	Q- I 2021	3,972,769.60
19	Q-III 2014	2,746,762.40	46	Q-II 2021	4,177,970.80
20	Q-IV 2014	2,697,695.40	47	Q-III 2021	4,327,358.00
21	Q- I 2015	2,728,180.70	48	Q-IV 2021	4,498,592.40
22	Q-II 2015	2,867,948.40	49	Q- I 2022	4,508,597.80
23	Q-III 2015	2,990,645.00	50	Q-II 2022	4,897,942.90
24	Q-IV 2015	2,939,558.70	51	Q-III 2022	5,066,994.30
25	Q- I 2016	2,929,269.00	52	Q-IV 2022	5,114,910.60
26	Q-II 2016	3,073,536.70	53	Q- I 2023	5,072,370.10
27	Q-III 2016	3,205,019.00	54	Q-II 2023	5,226,670.10

The above data plot can be shown in Figure 2.

Figure 2 presents a graphical representation of Indonesia's GDP data at Current Market Prices by Industry, measured in Billion Rupiahs, spanning from the first quarter of 2010 to the second quarter of 2022. The observed trend in the data pattern, as illustrated in the figure, indicates a discernible directional movement over the specified timeframe. This trend pattern provides valuable insights into the overall trajectory of Indonesia's economic output.

The minimum recorded data value occurred in the first quarter of 2010, registering at 1,603,771.90 billion Rupiahs. In contrast, the maximum value was documented in the second quarter of 2023, reaching IDR 5,226,670.10 billion. These extrema highlight the dynamic range of the GDP data, showcasing both the lowest and highest values within the given period.

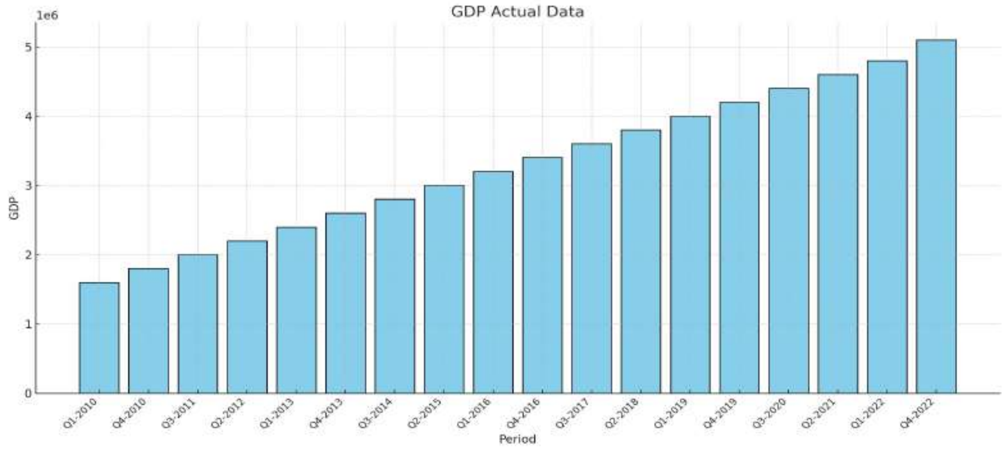

Figure 2: Indonesia's GDP Chart

The recognition of a discernible trend in the GDP data pattern serves as a rationale for considering the application of fuzzy time series for forecasting. The distinct fluctuations and directional movements in the data offer a foundation for exploring the potential of fuzzy time series methodology in capturing and predicting the intricate dynamics of Indonesia's economic output.

3.1. **Fuzzy Time Series Analysis.** The set of universes is derived from historical data through the establishment of minimum and maximum data bounds for the universes. In this context, specific parameters are defined to shape the universes: $d_1 = 0$,$d_2 = 100$, $D_{\min} = 1{,}603{,}771.90$, and $D_{\max} = 5{,}226{,}670.10$. These parameters lead to the formation of the universe set, denoted as $U = [1{,}603{,}771.90; 5{,}226{,}670.10]$.

To determine the number of intervals, *K*, the formula $K = 1 + 3.3 \cdot log(54)$ is utilized, resulting in

$K \approx 6.7168$, rounded to 7. Subsequently, fuzzy sets are derived by dividing the sum of intervals within U into K equal parts. Table 2 provides a clear representation of these fuzzy sets, delineating the intervals and corresponding linguistic values obtained from the historical data.

This systematic approach ensures a transparent explanation of the process involved in forming the set of universes, specifying the parameters used and how the intervals are determined. The subsequent representation in Table 2 further enhances the clarity of the derived fuzzy sets, establishing a foundation for the subsequent steps in the fuzzy time series modeling methodology.

Interval	Lower Bound	Upper Bound	Middle Value	Fuzzy Set
U_1	1,603,771.90	2,121,343.07	1,862,557.49	A_1
U_2	2,121,343.07	2,638,914.24	2,380,128.66	A_2
U_3	2,638,914.24	3,156,485.41	2,897,699.83	A_3
U_4	3,156,485.41	3,674,056.59	3,415,271.00	A_4
U_5	3,674,056.59	4,191,627.76	3,932,842.17	A_5
U_6	4,191,627.76	4,709,198.93	4,450,413.34	A_6
U_7	4,709,198.93	5,226,770.10	4,967,984.51	A_7

Table 2. Fuzzy set

After conducting a fuzzy time series analysis based on intervals, the set of speech universes and fuzzy sets obtained forecasting results, as shown in Table 3.

Table 3. Results of Indonesia's GDP Forecasting (Billion Rupiahs)

Period	GDP Value	Forecasting	Period	GDP Value	Forecasting
Q- I 2010	1,603,771.90	NA	Q-IV 2016	3,193,903.80	3,489,209.74
Q-II 2010	1,704,509.90	1,920,065.39	Q- I 2017	3,228,172.20	3,489,209.74
Q-III 2010	1,786,196.60	1,920,065.39	Q-II 2017	3,366,787.30	3,489,209.74
Q-IV 2010	1,769,654.70	1,920,065.39	Q-III 2017	3,504,138.50	3,489,209.74
Q- I 2011	1,834,355.10	1,920,065.39	Q-IV 2017	3,490,727.70	3,489,209.74
Q-II 2011	1,928,233.00	1,920,065.39	Q- I 2018	3,510,363.10	3,489,209.74
Q-III 2011	2,053,745.40	1,920,065.39	Q-II 2018	3,686,836.40	3,747,995.32
Q-IV 2011	2,015,392.50	1,920,065.39	Q-III 2018	3,842,343.00	3,972,655.34
Q- I 2012	2,061,338.30	1,920,065.39	Q-IV 2018	3,799,213.50	3,972,655.34
Q-II 2012	2,162,036.90	2,178,850.98	Q- I 2019	3,782,618.30	3,972,655.34
Q-III 2012	2,223,641.60	2,437,636.57	Q-II 2019	3,964,074.70	3,972,655.34
Q-IV 2012	2,168,687.70	2,437,636.57	Q-III 2019	4,067,358.00	3,972,655.34
Q- I 2013	2,235,288.50	2,437,636.57	Q-IV 2019	4,018,606.20	3,972,655.34
Q-II 2013	2,342,589.50	2,437,636.57	Q- I 2020	3,923,347.90	3,972,655.34
Q-III 2013	2,491,158.50	2,437,636.57	Q-II 2020	3,690,742.20	3,972,655.34
Q-IV 2013	2,477,097.50	2,437,636.57	Q-III 2020	3,897,851.90	3,972,655.34
Q- I 2014	2,506,300.20	2,437,636.57	Q-IV 2020	3,931,411.20	3,972,655.34
Q-II 2014	2,618,947.30	2,437,636.57	Q- I 2021	3,972,769.60	3,972,655.34
Q-III 2014	2,746,762.40	2,696,422.15	Q-II 2021	4,177,970.80	3,972,655.34
Q-IV 2014	2,697,695.40	2,962,396.23	Q-III 2021	4,327,358.00	4,231,440.92
Q- I 2015	2,728,180.70	2,962,396.23	Q-IV 2021	4,498,592.40	4,622,937.07
Q-II 2015	2,867,948.40	2,962,396.23	Q- I 2022	4,508,597.80	4,622,937.07
Q-III 2015	2,990,645.00	2,962,396.23	Q-II 2022	4,897,942.90	4,881,722.65
Q-IV 2015	2,939,558.70	2,962,396.23	Q-III 2022	5,066,994.30	4,967,984.51
Q- I 2016	2,929,269.00	2,962,396.23	Q-IV 2022	5,114,910.60	4,967,984.51
Q-II 2016	3,073,536.70	2,962,396.23	Q- I 2023	5,072,370.10	4,967,984.51
Q-III 2016	3,205,019.00	3,221,181.81	Q-II 2023	5,226,670.10	4,967,984.51

Referring to Table 3, the forecasted value for Indonesia's GDP in the upcoming period is projected to be 4,967,984.51 billion Rupiahs. This forecast is generated through the application of the fuzzy time series model, incorporating historical data and linguistic variables. The forecasted value provides an estimation of the economic output for the forthcoming period based on the established patterns and relationships identified in the historical GDP data.

Additionally, the Mean Absolute Percentage Error (MAPE) is calculated as 7.93%. MAPE is a measure of the accuracy of the forecasting model, representing the average percentage difference between the predicted and actual values. In this context, a MAPE of 7.93% suggests that, on average, the forecasted GDP values deviate by approximately 7.93% from the actual observed values. Lower MAPE values generally indicate a higher level of accuracy in the forecasting model.

Interpreting these results, the forecasted GDP value provides insight into the expected economic performance for the specified period, while the MAPE metric offers a quantitative measure of the accuracy of the forecasting model. A lower MAPE value indicates a more accurate forecast, implying that the fuzzy time series model has demonstrated a relatively precise ability to capture and predict the patterns in Indonesia's GDP data. However, it's essential to consider the specific context and requirements of the forecasting application when evaluating the adequacy of the model's performance.

3.2. Fuzzy Time Series using Particle Swam Optimization.

3.2.1. *Initial Parameter.* The PSO parameters include the number of particles, commonly chosen within the range of multiples of 5 to 100, the number of iterations, the weight of iterations (w) starting from 0.5 to 1, and a combination of c1 and c2, subject to the condition that $c1 + c2 \leq 4$. This paper adopts the PSO parameters as outlined in Table 4.

Table 4. PSO Parameter

• No.	PSO Parameter	Value
• 1	Number of iteration	50
• 2	Number of particles	10
• 3	Weight of iteration	0.5
• 4	c_1	1.5
• 5	c_2	1.5
• 6	r_1	0.3
• 7	r_2	0.2

Position and initial velocity of particles

The initial velocity of each particle is assumed to be zero. The number of dimensions for the particles is determined by subtracting one from the total number of particles, i.e., 7 – 1 = 6 dimensions. The initial velocities of the particles are presented in Table 5.

Table 5. The Initial Velocity of The Particle

• No.	• d_1	• d_2	• d_3	• d_4	• d_5	• d_6
• 1	• 0	• 0	• 0	• 0	• 0	• 0
• 2	• 0	• 0	• 0	• 0	• 0	• 0
• 3	• 0	• 0	• 0	• 0	• 0	• 0
• 4	• 0	• 0	• 0	• 0	• 0	• 0
• 5	• 0	• 0	• 0	• 0	• 0	• 0
• 6	• 0	• 0	• 0	• 0	• 0	• 0
• 7	• 0	• 0	• 0	• 0	• 0	• 0
• 8	• 0	• 0	• 0	• 0	• 0	• 0
• 9	• 0	• 0	• 0	• 0	• 0	• 0
• 10	• 0	• 0	• 0	• 0	• 0	• 0

The initial positions of each particle in the particle swarm optimization (PSO) algorithm are determined through a random generation process. The generated positions are constrained within the historical data bounds, specifically ranging from 1,603,771.90 to 5,226,770.10. It's worth noting that the values of both lower and upper bounds (1,603,771.90 and 5,226,770.10, respectively) are fixed and not included in the randomly generated positions.

Table 6 presents a detailed overview of these initial positions for each particle. The values listed in the table represent the randomly generated positions within the specified data bounds. The initial positions play a crucial role in initiating the PSO algorithm, influencing how particles explore the solution space in search of optimal parameter values for the fuzzy time series model.

Table 6. The Initial Position of The Particle

• No.	d_1	d_2	d_3	d_4	d_5	d_6
• 1	1,776,329.23	2,263,802.21	3,073,536.70	4,007,008.01	4,167,338.76	4,072,169.66
• 2	1,776,329.23	2,117,436.47	3,105,219.27	4,008,606.11	4,018,555.28	4,117,270.83
• 3	1,821,067.72	2,078,418.32	3,187,813.82	4,023,347.91	3,923,347.14	4,027,458.72
• 4	1,869,224.63	2,272,514.26	3,238,273.42	3,690,742.24	3,890,732.21	4,328,512.42
• 5	1,831,747.26	2,723,541.26	3,476,787.64	3,897,851.97	4,067,358.14	4,408,398.63
• 6	1,977,333.08	2,216,768.82	3,476,787.64	3,978,611.23	4,218,006.32	4,897,942.61
• 7	1,869,224.63	2,352,344.53	3,476,787.64	4,009,678.03	4,013,447.33	5,102,124.13
• 8	1,879,114.12	2,352,344.53	3,523,363.12	4,118,504.22	4,190,732.29	5,111,211.64
• 9	1,872,671.12	2,352,344.53	3,523,363.12	4,254,348.54	4,767,458.44	5,272,381.41
• 10	1,946,373.10	2,486,123.61	3,847,443.37	4,093,642.25	4,518,706.18	5,204,113.14

3.2.2. *Fuzzy time series PSO.* Optimum results of wide fuzzy time series intervals with PSO with the help of *Rstudio software.*

```
> pso_fts <- psoptim(fts_function, n=10, max.loop=50, w, c1, c2, xmin=xmin, xmax=xmax, vmax=c(2, 2), seed=5, anim=TRUE)
There were 50 or more warning (use warning() to see the first 50)
>
> pso_fts
$sol
            x1
[1,] 3625478.38

$val
[1] 5013524.47

>
> opt_interval <- sort(fts_function(fts_function(pso_fts$sol))
> opt_interval
[1] 1632199.23  2250184.80  2776079.46  3424865.36  3719698.16  4748846.20
>
```

Figure 3: Output Interval PSO

In Figure 3, the Particle Swarm Optimization (PSO) algorithm yields an optimum solution for the fuzzy time series model, resulting in a forecasted GDP value of 3,625,478.38. This optimal solution corresponds to a fitness value of 5,013,524.47. Additionally, the PSO algorithm identifies an optimal set of intervals for the fuzzy time series model, which is determined as follows: 1,632,199.23; 2,250,184.80; 2,776,079.46; 3,424,865.36; 3,719,698.16; 4,748,846.20.

These optimal intervals are then used to form fuzzy sets denoted as $A_1, A_2, ..., A_7$. Each fuzzy set interval is defined based on the identified optimum values and is represented as

$A_1 = (D_{\min} - d_1, x_1)$, $A_2 = (x_1, x_2)$, ..., $A_7 = (x_6, D_{\max} + d_2)$, where x_1 to x_6 is the determined interval boundaries. The resulting fuzzy sets, along with their respective intervals, are organized and presented in Table 7.

Table 7. Fuzzy Set Interval

Fuzzy set	Lower Bound	Upper Bound	Middle Value
A_1	1,603,771.90	1,632,199.23	1,617,985.57
A_2	1,632,199.23	2,250,184.80	1,941,192.02

Fuzzy set	Lower Bound	Upper Bound	Middle Value
A_3	2,250,184.80	2,776,079.46	2,513,132.13
A_4	2,776,079.46	3,424,865.36	3,100,472.41
A_5	3,424,865.36	3,719,698.16	3,572,281.76
A_6	3,719,698.16	4,748,846.20	4,234,272.18
A_7	4,748,846.20	5,226,670.10	4,987,758.15

After conducting fuzzy time series analysis based on fuzzy set intervals PSO forecasting results are shown in Table 8.

Table 8. Fuzzy Time Series_PSO Forecasting Results

Period	**GDP Value**	**Forecasting**	**Period**	**GDP Value**	**Forecasting**
Q- I 2010	1,603,771.90	NA	Q-IV 2016	3,193,903.80	3,221,181.81
Q-II 2010	1,704,509.90	1,812,287.65	Q- I 2017	3,228,172.20	3,221,181.81
Q-III 2010	1,786,196.60	2,246,097.50	Q-II 2017	3,366,787.30	3,221,181.81
Q-IV 2010	1,769,654.70	2,246,097.50	Q-III 2017	3,504,138.50	3,221,181.81
Q- I 2011	1,834,355.10	2,246,097.50	Q-IV 2017	3,490,727.70	3,982,655.34
Q-II 2011	1,928,233.00	2,246,097.50	Q- I 2018	3,510,363.10	3,982,655.34
Q-III 2011	2,053,745.40	2,246,097.50	Q-II 2018	3,686,836.40	3,982,655.34
Q-IV 2011	2,015,392.50	2,246,097.50	Q-III 2018	3,842,343.00	3,982,655.34
Q- I 2012	2,061,338.30	2,246,097.50	Q-IV 2018	3,799,213.50	3,982,655.34
Q-II 2012	2,162,036.90	2,246,097.50	Q- I 2019	3,782,618.30	3,982,655.34
Q-III 2012	2,223,641.60	2,246,097.50	Q-II 2019	3,964,074.70	3,982,655.34
Q-IV 2012	2,168,687.70	2,246,097.50	Q-III 2019	4,067,358.00	3,982,655.34
Q- I 2013	2,235,288.50	2,246,097.50	Q-IV 2019	4,018,606.20	3,982,655.34
Q-II 2013	2,342,589.50	2,246,097.50	Q- I 2020	3,923,347.90	4,444,340.92
Q-III 2013	2,491,158.50	2,246,097.50	Q-II 2020	3,690,742.20	4,444,340.92
Q-IV 2013	2,477,097.50	2,246,097.50	Q-III 2020	3,897,851.90	4,444,340.92
Q- I 2014	2,506,300.20	2,772,645.24	Q-IV 2020	3,931,411.20	4,444,340.92
Q-II 2014	2,618,947.30	2,772,645.24	Q- I 2021	3,972,769.60	4,444,340.92
Q-III 2014	2,746,762.40	2,772,645.24	Q-II 2021	4,177,970.80	4,444,340.92
Q-IV 2014	2,697,695.40	2,772,645.24	Q-III 2021	4,327,358.00	4,444,340.92
Q- I 2015	2,728,180.70	2,772,645.24	Q-IV 2021	4,498,592.40	4,743,338.12
Q-II 2015	2,867,948.40	2,772,645.24	Q- I 2022	4,508,597.80	4,743,338.12
Q-III 2015	2,990,645.00	2,772,645.24	Q-II 2022	4,897,942.90	4,743,338.12
Q-IV 2015	2,939,558.70	2,772,645.24	Q-III 2022	5,066,994.30	5,116,852.62
Q- I 2016	2,929,269.00	2,772,645.24	Q-IV 2022	5,114,910.60	5,116,852.62
Q-II 2016	3,073,536.70	3,221,181.81	Q- I 2023	5,072,370.10	5,116,852.62
Q-III 2016	3,205,019.00	3,221,181.81	Q-II 2023	5,226,670.10	5,116,852.62

Referring to Table 8, the forecasted value for Indonesia's GDP in the upcoming period (Q-III 2023) is projected to be 5,116,852.62 billion Rupiahs. This forecast is derived from the fuzzy time series model, which incorporates the optimized parameters obtained through the Particle Swarm Optimization (PSO) algorithm. The forecasted value represents an estimate of the economic output for the specified future period, based on the identified patterns and linguistic representations in the historical GDP data.

The fuzzy time series model, with the optimized intervals determined by PSO, contributes to a more accurate and refined forecasting process. The forecasted GDP value of 5,116,852.62 billion Rupiahs provides valuable insights for decision-makers, analysts, and stakeholders, aiding in anticipating and planning for the economic performance of Indonesia in Q-III 2023. This output represents the culmination of the fuzzy time series modeling and optimization efforts, offering a quantified projection for the specified period.

3.3. **Comparison of fuzzy time series and fuzzy time series PSOs.** The comparison of the accuracy of fuzzy time series and fuzzy time series PSO forecasting are the AIC and MAPE. The results of AIC and MAPE values can be seen in Table 9.

Table 9. Comparison of Forecasting Results

Method	AIC	MAPE
Fuzzy time series	2773.32	7.93%
Fuzzy time series PSO	2137.21	4.40%

Based on the findings in Table 9, it is evident that the fuzzy time series method combined with PSO outperforms the conventional fuzzy time series, as indicated by its smaller error value (MAPE). A representation of the accuracy comparison between fuzzy time series and fuzzy time series forecasting with PSO is presented in Figure 4.

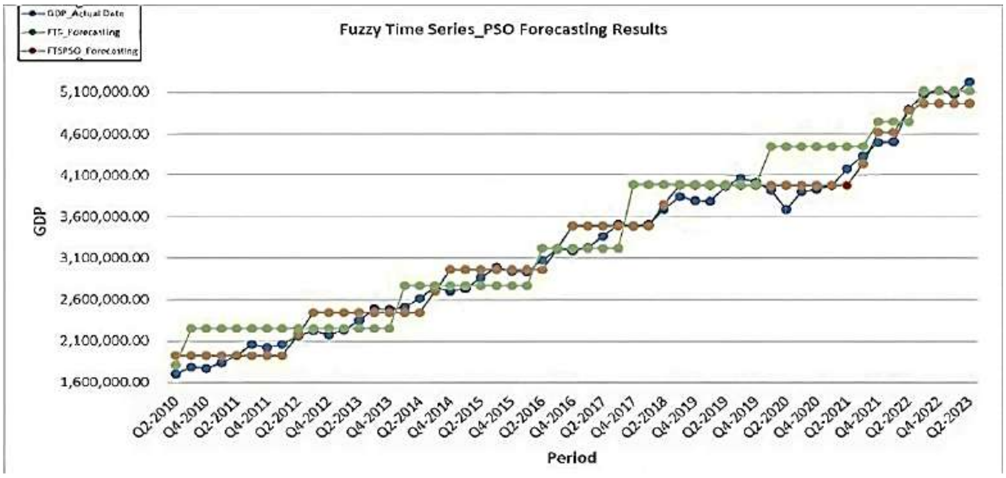

Figure 4: Fuzzy time series PSO Forecasting of Indonesia's GDP

3.4. **Figure 4. Fuzzy time series PSO Forecasting of Indonesia's GDP.** Figure 4 illustrates that the integration of the Particle Swarm Optimization (PSO) algorithm with the fuzzy time series method leads to an enhanced performance compared to the standard fuzzy time series alone. The plot demonstrates a closer alignment between the forecasted values obtained through the fuzzy time series method with PSO optimization and the actual Indonesia's GDP data. This closer alignment signifies that the optimized parameters, obtained through the PSO algorithm, contribute to a more accurate representation of the underlying patterns in the GDP data.

The overall conclusion drawn from this observation is that the combined approach, incorporating PSO for parameter optimization, improves the forecasting accuracy of the fuzzy time series model. The enhanced alignment between the forecasted values and the actual data suggests that the optimized parameters allow the model to capture and represent the complex dynamics of Indonesia's GDP more effectively. This outcome reinforces the value of meta-heuristic optimization techniques, such as PSO, in refining the fuzzy time series methodology for robust economic forecasting.

In summary, the results and discussions affirm that the integration of PSO with the fuzzy time series model is a promising approach for improving the accuracy of GDP forecasts. This finding holds significance for practitioners, policymakers, and researchers involved in economic forecasting, providing insights into effective methodologies for capturing and predicting the intricate dynamics of Indonesia's economic landscape.

4. CONCLUSION

Based on the comprehensive results and discussions, a robust conclusion can be drawn regarding the fuzzy time series predictions for Indonesia's GDP using particle swarm optimization (FTS-PSO). The model, optimized through the particle swarm optimization algorithm, successfully identified seven intervals that span the dynamic range from the lower limit of 1,603,771.90 to the upper limit of 5,226,770.10 in the historical data. The forecasted GDP value using FTS-PSO is 5,116,852.62 billion Rupiahs, with a remarkably low Mean Absolute Percentage Error (MAPE) value of 4.40%.

In comparison, the forecasting results for Indonesia's GDP using the standard fuzzy time series alone yielded a predicted value of 4,967,984.51 billion Rupiahs, accompanied by a higher MAPE value of 7.93%. This stark difference in MAPE values underscores the superiority of the FTS-PSO approach, as it demonstrates a significantly lower percentage deviation between the predicted and actual values.

The original theoretical and technical contributions of this paper lie in the successful integration of particle swarm optimization with fuzzy time series for GDP forecasting. The FTS-PSO model outperforms the standard fuzzy time series model, providing a more accurate representation of Indonesia's economic dynamics. This research contributes to the field by showcasing the effectiveness of meta-heuristic optimization, particularly PSO, in refining fuzzy time series models for enhanced accuracy in economic forecasting. The identification of optimized intervals and the subsequent reduction in MAPE value highlight the practical implications of this approach for policymakers, analysts, and researchers engaged in economic prediction. Overall, this paper adds valuable insights to the methodology of economic forecasting, emphasizing the potential of combining fuzzy time series with meta-heuristic algorithms for superior predictive performance.

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Follow-up on Manuscript Submission and Request for Publication Schedule

Ismail Djakaria <iskar@ung.ac.id>
Kepada: assistant.editor@ajmaa.org

6 Desember 2024 pukul 09.07

Dear Editor,

I am writing to follow up on the status of our manuscript titled "Indonesia's GDP Forecast: Evidence from Fuzzy Time Series Model Using Particle Swarm Optimization Algorithm" for publication in AJMAA.

We have sent the revised manuscript since 21 November 2024. Given the timeline and our academic requirements, we would like to kindly request if it would be possible to publish our manuscript on or before 7 December 2024. We believe this timeline aligns well with your upcoming issue schedule and would greatly support our academic objectives.

Please let us know if there is any additional information or action required from our side to facilitate the process. Thank you for your attention to this matter, and we look forward to your kind response.

Warm regards,
Ismail Djakaria

Universitas Negeri Gorontalo UNGMail

Ismail Djakaria <iskar@ung.ac.id>

Follow-Up on Manuscript Submission: "Indonesia's GDP Forecast: Evidence from Fuzzy Time Series Model Using Particle Swarm Optimization Algorithm

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Ismail Djakaria <iskar@ung.ac.id> 7 Desember 2024 pukul 12.55
Kepada: assistant.editor@ajmaa.org

I am writing to kindly follow up regarding the status of our manuscript titled "Indonesia's GDP Forecast: Evidence from Fuzzy Time Series Model Using Particle Swarm Optimization Algorithm," submitted to AJMAA.

We previously emailed on 6 Desember 2024 regarding this manuscript but have not yet received a response. As we mentioned earlier, the revised manuscript was submitted on 21 November 2024, and given the importance of this publication for our academic objectives, we would be truly grateful if it could be considered for publication on or before 7 December 2024.

We understand and deeply respect the review and publication process, but we are reaching out again due to the urgency of this timeline. Please let us know if there are any additional steps or information required to facilitate the process.

Thank you very much for your time and attention, and I sincerely hope for your kind response at your earliest convenience.

Warm regards,
Ismail Djakaria

Ismail Djakaria <iskar@ung.ac.id>

Request for Publication Date - AJMAA

Ismail Djakaria <iskar@ung.ac.id> 9 Desember 2024 pukul 08.39
Kepada: assistant.editor@ajmaa.org, Sever Dragomir <sever.dragomir@ajmaa.org>

I am writing to kindly follow up regarding the status of our manuscript titled "Indonesia's GDP Forecast: Evidence from Fuzzy Time Series Model Using Particle Swarm Optimization Algorithm," submitted to AJMAA.

We previously emailed on 6 December 2024 regarding this manuscript but have not yet received a response. As we mentioned earlier, the revised manuscript was submitted on 21 November 2024, and given the importance of this publication for our academic objectives, we would be truly grateful if it could be considered for publication on or before 9 December 2024.

We understand and deeply respect the review and publication process, but we are reaching out again due to the urgency of this timeline. Please let us know if there are any additional steps or information required to facilitate the process.

Thank you very much for your time and attention, and I sincerely hope for your kind response at your earliest convenience.

Warm regards,
Ismail Djakaria

UNGMail

Ismail Djakaria <iskar@ung.ac.id>

Request for Publication Date - AJMAA

Assistant Editor <assistant.editor@ajmaa.org> 10 Desember 2024 pukul 17.38
Balas Ke: assistant.editor@ajmaa.org
Kepada: Ismail Djakaria <iskar@ung.ac.id>, Sever Dragomir <sever.dragomir@ajmaa.org>

Dear Dr. Djakaria,

Thank you for reaching out.

The publication time at this stage is undefined, but expected to be before the end of the year (31 December 2024).

The reason for this is simple: the changes we have requited have not been implemented in the manuscript. We will endeavor to start this process ourselves, but at this stage the soonest opportunity to do so starts on the 19 December.

Meanwhile, it would be great if you would be able to provide some higher resolution images of your graph.

Best regards,

Camelia Crepelca
Assistant Editor
AJMAA

From: Ismail Djakaria [mailto:iskar@ung.ac.id]
Sent: Monday, 09 December, 2024 11:39
To: assistant.editor@ajmaa.org; Sever Dragomir
Subject: Request for Publication Date - AJMAA

[Kutipan teks disembunyikan]

Ismail Djakaria <iskar@ung.ac.id>

Request for Publication Date - AJMAA

Ismail Djakaria <iskar@ung.ac.id> 10 Desember 2024 pukul 18.49
Kepada: assistant.editor@ajmaa.org

Dear Dr. Crepelca,

Thank you for your email and for providing the update on the publication process. I appreciate your efforts and understand the current timeline.

As requested, I have attached higher-resolution versions of the graph for your review and use in the manuscript. Please let me know if there are any further adjustments or additional materials needed.

Thank you for your continued assistance, and I look forward to the next steps.

Best regards,
Ismail Djakaria

Ismail Djakaria <iskar@ung.ac.id>

Request for Publication Date - AJMAA

Assistant Editor <assistant.editor@ajmaa.org> 16 Desember 2024 pukul 18.34
Balas Ke: assistant.editor@ajmaa.org
Kepada: Ismail Djakaria <iskar@ung.ac.id>
Cc: Sever Dragomir <sever.dragomir@ajmaa.org>

Dear Dr. Djakaria,

Enclosed is a first draft of your prepared manuscript in our style in LaTeX.

We have found some things that we need from you at this stage, as follows:

1. ams subject classification. Preferably 2010 or newer; preferably primary + secondary
2. Figure 1. There was no original image
3. Figure 2. There was no original image
4. Any feedback regarding major issue with things such as tables or cross-references/bib items

Please send us these details and we will proceed with a more refined version.

Sincerely,

Camelia Crepelca
Assistant Editor
AJMAA

From: Ismail Djakaria [mailto:iskar@ung.ac.id]
Sent: Tuesday, 10 December, 2024 21:50
To: assistant.editor@ajmaa.org
Subject: Re: Request for Publication Date - AJMAA

[Kutipan teks disembunyikan]

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Request for Publication Date - AJMAA

Ismail Djakaria <iskar@ung.ac.id>
Kepada: assistant.editor@ajmaa.org
20 Desember 2024 pukul 16.15

Dear Assistant Editor,

Thank you for your detailed comments and for reviewing our manuscript. Below are our responses to the points raised:

1. **AMS Subject Classification**
   We have provided the AMS subject classifications as follows:
   - Primary: **91B** (Economic theory, forecasting)
   - Secondary: **62M** (Time series analysis) and **68T** (Artificial intelligence, fuzzy systems).
2. **Figure 1**
   As previously noted, the image used in Figure 1 is cited appropriately in the manuscript, with the source clearly written. Please let us know if additional details or modifications are needed.
3. **Figure 2**
   We have attached the revised version of Figure 2 in this email for your reference.
4. **Tables and References**
   We have reviewed the tables and references and found them suitable and correctly formatted. If there are specific concerns, we would be happy to address them further.

We hope this resolves the issues raised and look forward to receiving the next version of the manuscript.

Best regards,
Ismail Djakaria

Universitas Negeri Gorontalo UNGMail

Ismail Djakaria <iskar@ung.ac.id>

Follow-Up on Article Submission to AJMAA

Ismail Djakaria <iskar@ung.ac.id> 24 Desember 2024 pukul 09.19
Kepada: assistant.editor@ajmaa.org, Sever Dragomir <sever.dragomir@ajmaa.org>

Dear Editor,

I hope this message finds you well. I am writing to follow up on the status of our article, titled "Indonesia's GDP Forecast: Evidence from Fuzzy Time Series Model Using Particle Swarm Optimization Algorithm," which we submitted to The Australian Journal of Mathematical Analysis and Applications.

We have provided all the necessary requirements as outlined in the submission guidelines and addressed any feedback or revisions requested during the review process. However, we have yet to receive any updates regarding the publication status of our manuscript.

We kindly request an update on the progress of our submission. If there are additional requirements or clarifications needed, please let us know, and we would be happy to address them promptly.

Thank you for your time and assistance. We look forward to your response.

Best regards,
Ismail Djakaria

UNGMail

Ismail Djakaria <iskar@ung.ac.id>

Follow-Up on Article Submission to AJMAA

Ismail Djakaria <iskar@ung.ac.id> 27 Desember 2024 pukul 09.29
Kepada: assistant.editor@ajmaa.org, Sever Dragomir <sever.dragomir@ajmaa.org>

Dear Editor,

I hope this message finds you well. I am writing to follow up on the status of our article, titled "Indonesia's GDP Forecast: Evidence from Fuzzy Time Series Model Using Particle Swarm Optimization Algorithm," which we submitted to The Australian Journal of Mathematical Analysis and Applications.

We have provided all the necessary requirements as outlined in the submission guidelines and addressed any feedback or revisions requested during the review process. However, we have yet to receive any updates regarding the publication status of our manuscript.

We kindly request an update on the progress of our submission. If there are additional requirements or clarifications needed, please let us know, and we would be happy to address them promptly.

Thank you for your time and assistance. We look forward to your response.

Best regards,
Ismail Djakaria

Universitas Negeri Gorontalo UNGMail

Ismail Djakaria <iskar@ung.ac.id>

Follow-Up on Article Submission to AJMAA

Sever Dragomir <sever.dragomir@ajmaa.org> 28 Desember 2024 pukul 04.59
Kepada: Ismail Djakaria <iskar@ung.ac.id>, assistant.editor@ajmaa.org

Dear Dr. Ismail Djakaria,

As you are aware here is the Holiday season. People are in vacations and usually they come back to work in the second week of January.

I am sure that the Assistant editor will address you query at once she is back at work.

Happy New Year 2025!

Sever Dragomir

Ismail Djakaria <iskar@ung.ac.id>

Follow-Up on Article Submission to AJMAA

Assistant Editor <assistant.editor@ajmaa.org> 30 Desember 2024 pukul 05.01
Balas Ke: assistant.editor@ajmaa.org
Kepada: Ismail Djakaria <iskar@ung.ac.id>

Dear Dr. Djakaria,

We have sent an e-mail on 16/December with a prepared manuscript and requesting some additional information.

We will re-send this today.

Please let us know whether you have received it.

Sincerely,

Camelia Crepelca
Assistant Editor
AJMAA

From: Ismail Djakaria [mailto:iskar@ung.ac.id]
Sent: Friday, 27 December, 2024 12:30
To: assistant.editor@ajmaa.org; Sever Dragomir
Subject: Follow-Up on Article Submission to AJMAA

[Kutipan teks disembunyikan]

Ismail Djakaria <iskar@ung.ac.id>

RE: Request for Publication Date - AJMAA

Assistant Editor <assistant.editor@ajmaa.org> 30 Desember 2024 pukul 05.02
Balas Ke: assistant.editor@ajmaa.org
Kepada: Ismail Djakaria <iskar@ung.ac.id>

E-mail from 16 December.

From: Assistant Editor [mailto:assistant.editor@ajmaa.org]
Sent: Monday, 16 December, 2024 21:34
To: 'Ismail Djakaria'
Cc: 'Sever Dragomir'
Subject: RE: Request for Publication Date - AJMAA

Dear Dr. Djakaria,

Enclosed is a first draft of your prepared manuscript in our style in LaTeX.

We have found some things that we need from you at this stage, as follows:

1. ams subject classification. Preferably 2010 or newer; preferably primary + secondary
2. Figure 1. There was no original image
3. Figure 2. There was no original image
4. Any feedback regarding major issue with things such as tables or cross-references/bib items

Please send us these details and we will proceed with a more refined version.

Sincerely,

Camelia Crepelca
Assistant Editor
AJMAA

From: Ismail Djakaria [mailto:iskar@ung.ac.id]
Sent: Tuesday, 10 December, 2024 21:50
To: assistant.editor@ajmaa.org
Subject: Re: Request for Publication Date - AJMAA

Dear Dr. Crepelca,

Thank you for your email and for providing the update on the publication process. I appreciate your efforts and understand the current timeline.

As requested, I have attached higher-resolution versions of the graph for your review and use in the manuscript. Please let me know if there are any further adjustments or additional materials needed.

Thank you for your continued assistance, and I look forward to the next steps.

Best regards,
Ismail Djakaria

Response to Manuscript Review Comments – Submission Update

Ismail Djakaria <iskar@ung.ac.id> 30 Desember 2024 pukul 09.42
Kepada: assistant.editor@ajmaa.org

Dear Assistant Editor,

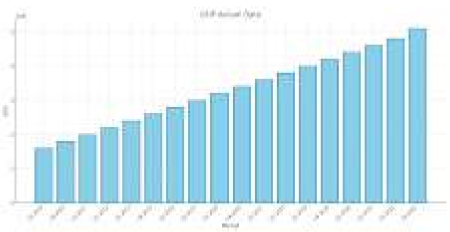
Thank you for your detailed comments and for reviewing our manuscript. Below are our responses to the points raised:

1. **AMS Subject Classification**
   We have provided the AMS subject classifications as follows:
   - Primary: **91B** (Economic theory, forecasting)
   - Secondary: **62M** (Time series analysis) and **68T** (Artificial intelligence, fuzzy systems).
2. **Figure 1**
   As previously noted, the image used in Figure 1 is cited appropriately in the manuscript, with the source clearly written. Please let us know if additional details or modifications are needed.
3. **Figure 2**
   We have attached the revised version of Figure 2 in this email for your reference.
4. **Tables and References**
   We have reviewed the tables and references and found them suitable and correctly formatted. If there are specific concerns, we would be happy to address them further.

We initially sent this information on **20 December 2024** and are resending it now to ensure clarity and alignment. We hope the manuscript can be finalized and published this month.

Thank you for your time and assistance.

Best regards,
Ismail Djakaria



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UNGMail

Ismail Djakaria <iskar@ung.ac.id>

RE: Response to Manuscript Review Comments - Submission Update

Assistant Editor <assistant.editor@ajmaa.org> 30 Desember 2024 pukul 17.49
Balas Ke: assistant.editor@ajmaa.org
Kepada: Ismail Djakaria <iskar@ung.ac.id>

Dear Dr. Djakaria,

Please send the image of Figure 1, or we can remove references to it from your paper (as "Figure 1") since it is not there.

Enclosed is your paper with the Figure 1 using a placeholder.

We are looking forward to your reply.

Best regards,

Camelia Crepelca
Assistant Editor
AJMAA

From: Ismail Djakaria [mailto:iskar@ung.ac.id]
Sent: Monday, 30 December, 2024 12:43
To: assistant.editor@ajmaa.org
Subject: Response to Manuscript Review Comments – Submission Update

Dear Assistant Editor,

Thank you for your detailed comments and for reviewing our manuscript. Below are our responses to the points raised:

1. **AMS Subject Classification**
   We have provided the AMS subject classifications as follows:
   - Primary: **91B** (Economic theory, forecasting)
   - Secondary: **62M** (Time series analysis) and **68T** (Artificial intelligence, fuzzy systems).
2. **Figure 1**
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   We have reviewed the tables and references and found them suitable and correctly formatted. If there are specific concerns, we would be happy to address them further.

We initially sent this information on **20 December 2024** and are resending it now to ensure clarity and alignment. We hope the manuscript can be finalized and published this month.

Thank you for your time and assistance.

Best regards,
Ismail Djakaria

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Ismail Djakaria <iskar@ung.ac.id>

RE: Response to Manuscript Review Comments - Submission Update

Assistant Editor <assistant.editor@ajmaa.org> 31 Desember 2024 pukul 06.59
Balas Ke: assistant.editor@ajmaa.org
Kepada: Ismail Djakaria <iskar@ung.ac.id>

Dear Dr. Djakaria,

We have published your paper online in a preliminary form, while we await your image of Figure 1. Please send it as soon as possible. We will update the online version once we receive this image.

Meanwhile, it has been published with the date of 31/December as we mentioned earlier, and it is available as part of our Volume 21. (Link: https://ajmaa.org/Volumes/Volume_21_Issue_2_2024.php)

Sincerely,

Camelia Crepelca
Assistant Editor
AJMAA

[Kutipan teks disembunyikan]

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