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| RESEARCH ARTICLE

Forecasting *Theobroma Cacao* Value of Production in the Philippines Using Time Series Modeling Approach

Elaine May D. Magdaraog
Saint Mary's University, School of Graduate Studies, Nueva Vizcaya, Philippines
Corresponding Author: Elaine May D. Magdaraog **E-mail**: hed-dmmagdaraog@smu.edu.ph

| ABSTRACT

Cacao production contributes significantly to the Philippine agricultural sector, and having reliable forecasts of its value is necessary to guide policy decisions, investments, and industry strategies. This study aimed to analyze historical trends in the cacao value of production from 2000 to 2025 and forecast production value for 2027 by applying time series models. Using data from the Philippine Statistics Authority, several modeling techniques were tested, including linear, exponential, polynomial (quadratic to sextic), moving average, exponential smoothing, and autoregression. The models were then assessed using the coefficient of determination (R^2) and standard error (SE) to determine which produced the most reliable forecasts. The quintic model emerged as the best fit since it provided the most accurate forecasted values and showed strong explanatory power. For 2027, the projected value is 5,070.934 million pesos. These findings give policymakers, agricultural agencies, and those in the cacao industry a reliable reference for anticipating production trends. Based on the results, the study recommends using the quintic model for planning, resource allocation, and program development to help sustain growth and improve the resilience of the cacao sector.

| KEYWORDS

agricultural forecasting; cacao production; mathematical modeling; nonlinear trends; time series analysis; Philippines

| ARTICLE INFORMATION

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1. Introduction

The cacao tree, known scientifically as Theobroma cacao L., is grown in the tropics, primarily in agroforestry systems, to yield seeds, a valuable raw material for the chocolate industry (Nieves-Orduña et al., 2024). It is a tropical crop commonly known as cacao or cocoa that belongs to the Malvaceae family and the genus Theobroma. Out of the twenty-two (22) species that make up the Theobroma genus, the most valuable and widely grown and cultivated is the Theobroma cacao L., primarily due to the economic value of its seeds (Kongor et al., 2024). Cacao (Theobroma cacao) is a crop that holds significant economic and ecological importance all over the world, especially in the Philippines, where the tropical climate provides suitable conditions for its growth and cultivation (Paguntalan et al., 2020). The cultivation of cacao in the Philippines promotes rural development and provides smallholder farmers with promising economic opportunities. Studies have shown that farmers and processors can gain substantial investment returns (Lirag, 2021).

According to Asir et al. (2019), the cacao industry plays a significant role in the economy's growth, with stakeholders across the value chain having the ability to impact both the quality and the continuity of the cacao production. Accurate forecasting will greatly benefit companies and producers in the cacao industry in developing efficient business plans, making informed investment decisions, and implementing adaptive measures that guarantee long-term profitability and growth of the sector. Research using exponential smoothing models, such as in Lampung Province, Indonesia, shows the effectiveness of time series methods for agricultural forecasting (JL & Maryani, 2023). Without reliable forecasts, stakeholders may find it difficult to respond efficiently to challenges and opportunities in the cacao industry.

In addition, limited studies have quantitatively investigated production value trends using rigorous methods for forecasting specifically related to cacao production in the Philippines. Most existing studies focus on qualitative analyses or broader agricultural statistics, and do not provide specific predictive tools. For instance, a value-chain study by Aguila (2018) gathered in-depth qualitative data on the roles, costs, and value addition of each actor but did not include quantitative forecasting tools, whereas a study by Te Huy and Antipuesto (2024) focused on forecasting cacao bean farmgate prices using an ARIMA model rather than production value. This creates a gap in the availability of accurate, model-based predictive tools for estimating cacao value of production. Local studies on sustainability programs in the cacao industry, such as those conducted in Davao del Norte, Philippines, have shown the need for strategic planning that uses data-driven tools (Penora & Magallon, 2024). Moreover, research on the market dynamics and online presence of cacao products in the Bicol Region also points to how reliable production forecasts can improve the industry's competitiveness (Lirag & Ramirez, 2024).

Overall, this research aims to bridge the gap between statistical modeling and real-world agricultural decision-making in the Philippine cacao industry. Specifically, this study aimed to: 1) determine the trend of the cacao value of production from 2000 to 2025; 2) construct time series models of the cacao value of production using the following models: a) exponential, b) linear, c) polynomial (quadratic, cubic, quartic, quintic, sextic), d) moving average, e) exponential smoothing, and f) autoregression to predict the value of production for the year 2027; and 3) determine the best-fit model and the predicted cacao value of production in the year 2027. While the study does not establish causal relationships, the findings may serve as a basis for future research and may contribute to data-driven planning and policy strategies for improving and managing cacao production value in the Philippines.

2. Materials and Methods

The study used a quantitative approach, utilizing secondary data to evaluate trends and historical patterns to make predictive estimates. This study used secondary data obtained from the official Philippine Statistics Authority (PSA) database, OpenSTAT, which is widely recognized locally and internationally as a reliable source of comprehensive and accurate statistics on key agricultural indicators, including the value of production. The dataset consists of the annual cacao value of production (in million pesos) for 2000-2025. Using a time series modeling approach, the aim was to analyze the trend of the cacao value of production and predict its future value.

2.1 Data Collection and Procedures

The data collection process involved downloading and compiling annual cacao value of production data records from the PSA OpenSTAT portal. The data was then double-checked to ensure completeness, check trends, and identify possible variations. The data were then organized in Microsoft Excel, with the years numerically coded for easier analysis (e.g., 2000 = 1, 2001 = 2, …, 2025 = 26). Through this coding system, it was possible to construct several time series models. A total of ten different models were constructed, including the following: exponential, linear, polynomial (quadratic, cubic, quartic, quintic, sextic), moving average, exponential smoothing, and first autoregression.

2.2 Statistical Analysis

Initially, trend analysis was performed in Microsoft Excel by fitting various trendlines to the dataset to determine the general direction and the magnitude of change over time. The study then tested several time series models. The accuracy of each model was measured using the coefficient of determination (R^2) and the standard error (SE) of estimate to evaluate both explanatory power and predictive power. The best-fit model for forecasting was then selected based on statistical fit and its accuracy in future prediction values. The best-fit model was then applied to forecast the cacao value of production for the year 2027.

3. Results and Discussion

3.1 Trend of the Cacao Value of Production in the Philippines

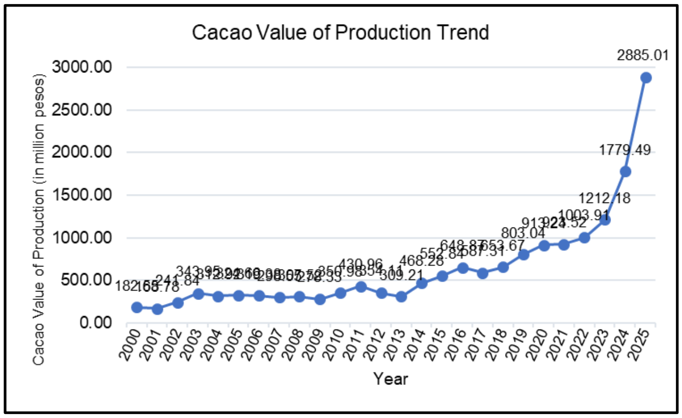

Figure 1. The Trend of the Cacao Value of Production in the Philippines from 2000 to 2025

The trend shown in Figure 1 illustrates the overall growth in the cacao value of production in the Philippines from 2000 to 2025. While there were some fluctuations in the earlier years, particularly a decline in 2001, 2004, 2006-2007, 2009, 2012-2013 and 2017, the general pattern reveals a consistent upward trajectory. Beginning in 2014, the value of production started to increase gradually, with a more noticeable and sustained rise observed from 2018 onward. The most significant growth occurred in the last seven years of the series; the cacao value of production increased a lot, from 803 million pesos in 2019 to 2,885 million pesos in 2025. This sharp increase suggests a period of expansion and improvement in the cacao industry. Various factors could be responsible for this increase, including enhanced agricultural methods, more investments in cacao, government programs that promote the sector, and the growing demand for cacao goods in the market. According to the Department of Agriculture, cacao production reached 10,565 metric tons in 2019, almost 23% greater than the amount produced in the previous year, 2018 (Balatico et al., 2024). In line with the observed upward trend, CEIC (2025) reported that the value of cacao crop production reached a record high of 748 million pesos by December 2024 alone, indicating a substantial year-end increase. Research conducted by Placencia et al. (2025) on smallholder cacao farmers in Davao de Oro gives more insight into the significance of farmer education and experience in enhancing technical efficiency. These are important aspects that are likely to contribute to the expansion of the cacao industry. These developments suggest a stronger cacao sector with promising potential for continued growth in the coming years.

3.2 Time Series Models

The following figure represents the trends of Cacao Value of Production over time using various mathematical methods.

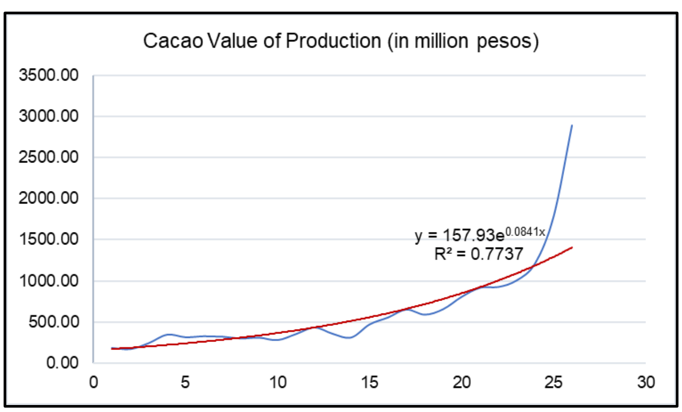

Figure 2. Exponential Model

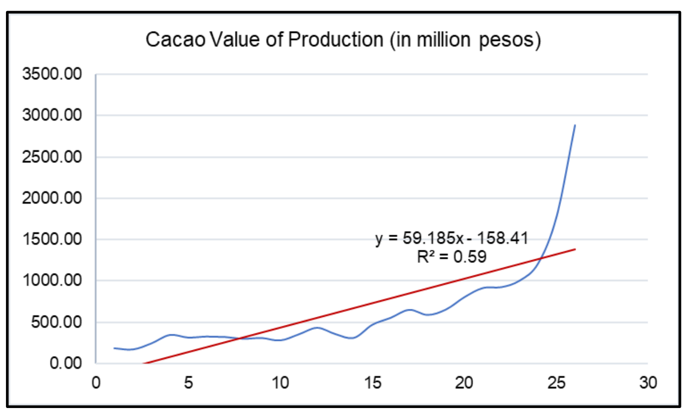

Figure 3. Linear Model

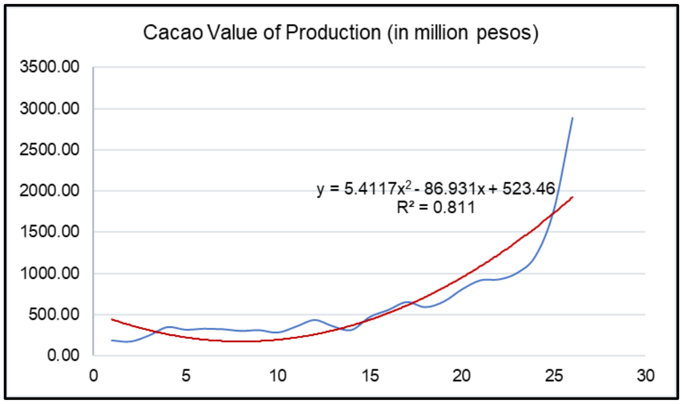

Figure 4. Quadratic Model

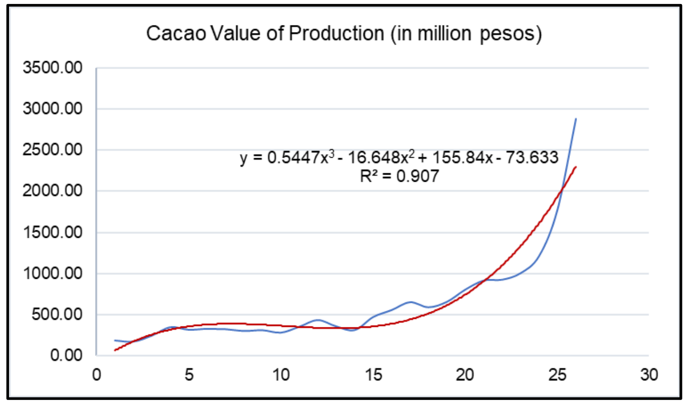

Figure 5. Cubic Model

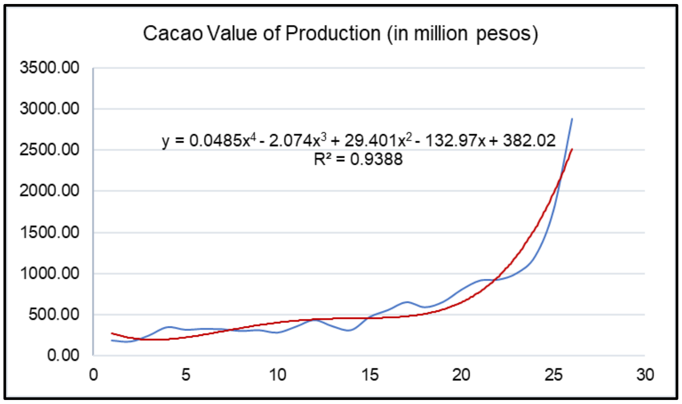

Figure 6. Quartic Model

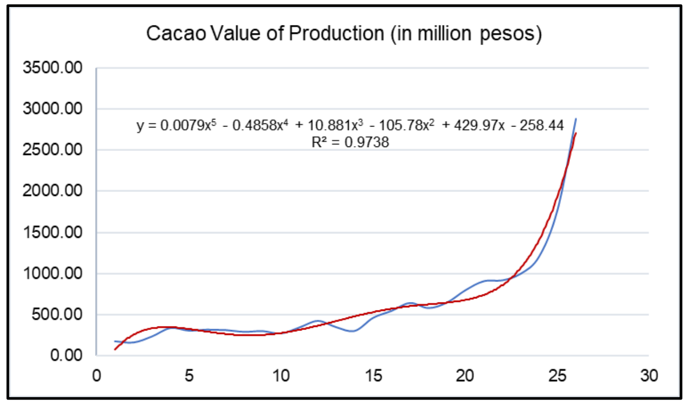

Figure 7. Quintic Model

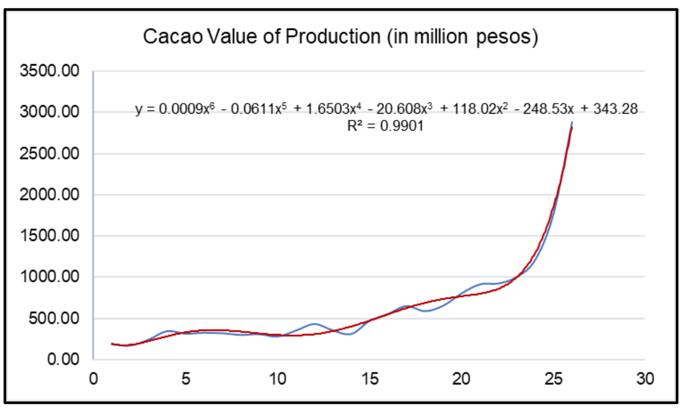

Figure 8. Sextic Model

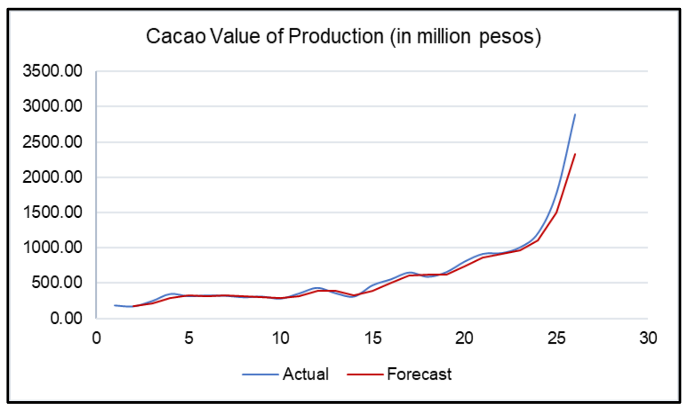

Figure 9. Moving Average Model

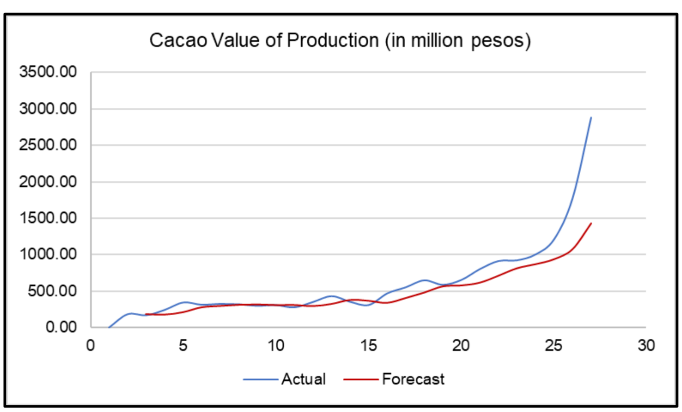

Figure 10. Exponential Smoothing

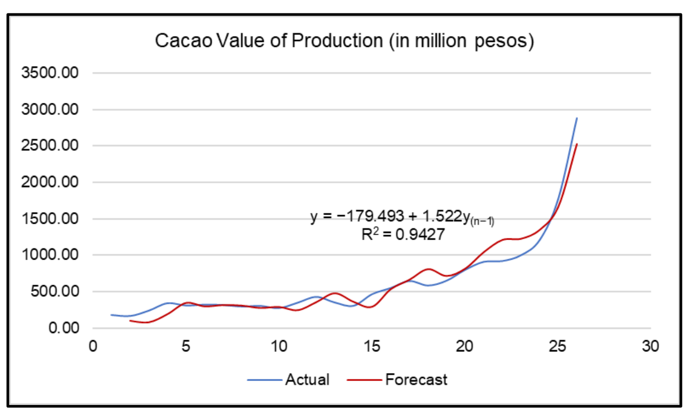

Figure 11. First Autoregression

Figure 2 shows the exponential model of Cacao Value of Production in the Philippines from year 2000 to 2025, with the equation $y = 157.93e^{0.0841x}$ and an R^2 value of 0.7737, which indicates that around 77.37% of the variance in Cacao Value of Production can be explained by the exponential model.

Figure 3 shows the linear model of Cacao Value of Production in the Philippines from year 2000 to 2025, with the equation $y = 59.185x - 158.41$ and an R^2 value of 0.59, which indicates that around 59% of the variance in Cacao Value of Production can be explained by the linear model.

Figure 4 shows the quadratic model of Cacao Value of Production in the Philippines from year 2000 to 2025, with the equation $y = 5.4117x^2 - 86.931x + 523.46$ and an R^2 value of 0.811, which indicates that around 81.1% of the variance in Cacao Value of Production can be explained by the quadratic model.

Figure 5 shows the cubic model of Cacao Value of Production in the Philippines from year 2000 to 2025, with the equation $y = 0.5447x^3 - 16.648x^2 + 155.84x - 73.633$ and an R^2 value of 0.907, which indicates that around 90.7% of the variance in Cacao Value of Production can be explained by the cubic model.

Figure 6 shows the quartic model of Cacao Value of Production in the Philippines from year 2000 to 2025, with the equation $y = 0.0485x^4 - 2.074x^3 + 29.401x^2 - 132.97x + 382.02$ and an R^2 value of 0.9388, which indicates that around 93.88% of the variance in Cacao Value of Production can be explained by the quartic model.

Figure 7 shows the quintic model of Cacao Value of Production in the Philippines from year 2000 to 2025, with the equation $y = 0.0079x^5 - 0.4858x^4 + 10.881x^3 - 105.78x^2 + 429.97x - 258.44$ and an R^2 value of 0.9738, which indicates that around 97.38% of the variance in Cacao Value of Production can be explained by the quintic model.

Figure 8 shows the sextic model of Cacao Value of Production in the Philippines from year 2000 to 2025, with the equation $y = 0.0009x^6 - 0.0611x^5 + 1.6503x^4 - 20.608x^3 + 118.02x^2 - 248.53x + 343.28$ and an R^2 value of 0.9901, which indicates that around 99.01% of the variance in Cacao Value of Production can be explained by the sextic model.

Figure 9 shows the moving average model with an interval of 2 for the Cacao Value of Production in the Philippines from year 2000 to 2025.

Figure 10 shows the exponential smoothing model with a damping factor of 0.5 for the Cacao Value of Production in the Philippines from year 2000 to 2025.

Figure 11 shows the first autoregression model of Cacao Value of Production in the Philippines from year 2000 to 2025 with the equation $y = -179.493 + 1.522y_{n-1}$, where y is the value of cacao production in the previous year (n-1), and an $R^2 = 0.9427$ which indicates that around 94.27% of the variances in Cacao Value of Production can be explained by the first autoregression model.

3.3 Best Fit Model and Prediction

Table 1. Summary of Models with Corresponding Equations, R^2, SE, and Predicted Values for the Year 2027

Model	Equation	R^2	SE	2027 Predicted Values
Exponential	$y = 157.93e^{0.0841x}$	0.7737	327.747	1663.954
Linear	$y = 59.185x - 158.41$	0.59	385.152	1498.77
Quadratic	$y = 5.4117x^2 - 86.931x + 523.46$	0.811	267.14	2332.165
Cubic	$y = 0.5447x^3 - 16.648x^2 + 155.84x - 73.633$	0.907	191.625	3195.109
Quartic	$y = 0.0485x^4 - 2.074x^3 + 29.401x^2 - 132.97x + 382.02$	0.9388	159.016	3991.612
Quintic	$y = 0.0079x^5 - 0.4858x^4 + 10.881x^3 - 105.78x^2 + 429.97x - 258.44$	0.9738	128.228	5070.934
Sextic	$y = 0.0009x^6 - 0.0611x^5 + 1.6503x^4 - 20.608x^3 + 118.02x^2 - 248.53x + 343.28$	0.9901	5429.157	30039.9
Moving Average Interval=2	-	-	439.32	2608.63
Exponential Smoothing Damping Factor=0.5	-	-	444.619	2155.848
First Autoregression	$y = -179.493 + 1.522y_{n-1}$	0.9427	145.252	6231.524

Table 1 shows various time series models for forecasting the cacao value of production, along with their corresponding R^2 and standard error (SE) values. Among all the models, the quintic model was considered the best fit because it has a high R^2 value and the lowest standard error (R^2 = 0.9738, SE = 128.228). The model suggests that this is the most reliable and accurate for forecasting cacao production in 2027. The sextic model recorded the highest R^2 value (0.9901), explaining 99.01% of the variance; however, its very high standard error (5429.157) limits its accuracy for forecasting. This unusually large standard error suggests overfitting, where the model captures noise rather than the true underlying trend. In contrast, simpler models such as the linear model (R^2 = 0.59, SE = 385.152) accounted for less variability, suggesting that the cacao value of production follows a more complex nonlinear trend. The autoregressive model (R^2 = 0.9427), which reflects the strong influence of previous-year values on current production, also performed reasonably well. However, its standard error (145.252) is slightly higher than that of the quintic model, which limits its accuracy for forecasting. Some models such as moving average and exponential smoothing do not have R^2 values, hence evaluation was primarily based on their standard error. Overall, the analysis shows that higher-order polynomial models, especially the quintic, are better at capturing the nonlinear growth patterns of cacao value of production and offering more reliable forecasts. Using the model, the predicted cacao value of production in 2027 is approximately 5,070.934 million pesos.

Related studies have demonstrated the effectiveness of nonlinear and high-order polynomial models in capturing agricultural dynamics, offering credibility to their efficacy. According to Nandi (2020), there is a theoretical connection between autoregressive time-series models of the same order and polynomial models, allowing for the representation of finite-degree polynomials. Muniz et al. (2017) also showed that nonlinear regression models produced better fits when residual dependencies were considered in modeling cacao fruit growth.

3.4 Limitations

This study, while providing a rigorous time series analysis, has several limitations that guide future research. The analysis relied solely on secondary data, excluding relevant external factors such as global prices, production volume, weather conditions, and other key variables. Future research may examine key influencing factors, including pest and disease prevalence, soil health, farming technology, training programs, and market dynamics, as well as conduct region-specific and longitudinal analyses. The use of advanced forecasting models, including ARIMA and machine learning techniques, may further improve predictive accuracy and support more responsive agricultural planning and policy-making.

4. Conclusions

The study reveals an overall upward trend in the cacao value of production in the Philippines from 2000 to 2025, indicating a growing and increasingly robust industry despite intermittent fluctuations. The notable expansion from 2019 to 2025 highlights strong potential for sustained development. Time series analysis examined several models, with the quintic model emerging as the most accurate and reliable, as evidenced by its high R^2 value and lowest standard error. Forecast results indicate that the cacao value of production may reach approximately 5,070.934 million pesos in 2027, suggesting a continued upward trend in the coming years. These findings provide valuable support for policymakers, agricultural planners, and industry stakeholders in shaping strategies and guiding investment decisions. The study underscores the importance of data-driven forecasting and prioritizing efforts to increase production value to strengthen the economic contribution of the cacao industry. By utilizing these insights, stakeholders can promote sustainable development, enhance sector resilience, and ensure the long-term success of cacao production in the Philippines.

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Conflicts of Interest
The author declares no conflict of interest.

ORCID iD: https://orcid.org/0009-0004-5992-2998

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