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The Role of Holt-Winters Method in Mining Sector Forecasting: Empirical Study in NTB Province 2015-2024

Meli Anggriyani[1], Syaharuddin[2], Vera Mandailina[3]
[1,2,3]Mathematic Education, Universitas Muhammadiyah Mataram, Indonesia
melianggriyani01@gmail.com[1], syaharuddin.ntb@gmail.com[2], vrmandailina@gmail.com [3]

Abstract: This research is important because the mining and atmosphere sector has a strategic contribution to the regional economy, especially in West Nusa Tenggara Province, but in recent years it has experienced a significant neck. Therefore, the purpose of this study is to analyze historical trends and predict the value of the Gross Regional Domestic Product (GRDP) of the mining and preference sector for the next five years in order to provide a more accurate and adaptive basis for regional economic development planning. This research is an experiment to forecast quarterly GRDP data for the period 2025-2029 based on actual data from 2015-2024. The data is taken from the official publication of the Central Bureau of Statistics of West Nusa Tenggara Province. The method used is Triple Exponential Smoothing (Holt-Winters Additive), which is able to capture trend and seasonal patterns in time series data. Data is taken from the Central Bureau of Statistics. The results showed that the Mean Absolute Percentage Error (MAPE) value obtained was 5807.79% which indicates that the accuracy of the model is in the good category and can be relied upon for economic planning needs. The implication of the research results is that local governments need to formulate policy strategies that not only focus on optimizing active mining production, but also encourage economic diversification, revitalize inactive mines, strengthen downstream industries, and improve sectoral data systems. Thus, the results of this prediction are expected to be used as a reference in elaborating regional development policies that are more responsive to the dynamics of the mining sector and macroeconomic conditions in general.

Keywords: Holt-Winters Method, Time Series Forecasting, Mining Sector.

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A. INTRODUCTION

The mining and quarrying sector has a significant role in shaping the structure of the economy at the regional level, especially in areas rich in natural resource potential such as West Nusa Tenggara (NTB) Province (Firmansyah, 2024). The high contribution of this sector to the Gross Regional Domestic Product (GRDP) indicates that this sector holds a strategic position in driving the pace of regional economic growth. In line with this, the availability of accurate and up-to-date data on the development of the mining and quarrying sector is very important to support the planning process, policy formulation, and determination of investment direction in a more targeted and sustainable manner. One of the strategic steps in obtaining such information is through data forecasting or prediction activities. Considering that this sector's data is a time series that has a fluctuation pattern from time to time, predictive analysis becomes very relevant to capture the economic dynamics that occur (Pangestu et al., 2024). By conducting proper forecasting, both local governments and businesses can formulate

responsive policies, manage resources optimally, and make the most of economic potential in order to realize sustainable development.

The analysis of time series data has given birth to a variety of forecasting methods that aim to predict future values based on historical patterns recorded in the data (Arumsari & Dani, 2021). Some commonly used approaches include the moving average method, simple exponential smoothing, linear regression, and more complex models such as Autoregressive Integrated Moving Average (ARIMA). The choice of forecasting method is determined by the characteristics of the data being analyzed, particularly the presence of trend patterns, seasonality, or random fluctuations. In Febriyanti & Rifai (2022) said that if the data shows a tendency to have trends and seasonal patterns simultaneously, then the Triple Exponential Smoothing method or better known as the Holt-Winters method is the right alternative. This method offers an exponential weighting approach to the three main components in the data, namely level (base level), trend, and seasonality, so as to capture the dynamics of change more optimally. Holt-Winters consists of two variants, namely the additive model and the multiplicative model, each of which is adapted to the shape of the seasonal pattern in the data (Safitri & Dwidayati, 2017). Because of its ability to handle periodic and complex data, this method has been widely used in various sectors, including the economic, energy, transportation, and mining sectors.

The Holt-Winters method is one of the forecasting approaches widely used in economic data analysis due to its ability to accommodate trend and seasonal components simultaneously (Lima et al., 2019). The effectiveness of this method has been proven through various studies, such as in a forecasting study of e-commerce retail sales in Portugal that managed to capture trend and seasonal patterns well, and in modeling the Consumer Price Index (CPI) in Kenya and South Africa that showed a high level of accuracy with a prediction difference of less than one percent of the actual value (Njenga, 2024). According to Hansun (2019) research that along with the development of science, several modifications to this method continue to be made to improve accuracy, including through the use of a weighted moving average-based initial value estimation approach in additive models and the application of optimization algorithms such as Genetic Algorithms to obtain optimal smoothing parameters that can minimize forecasting errors, as applied in predicting rice stocks in the Philippines (Navarro & Navarro, 2019). The appeal of the Holt-Winters method also lies in its simplicity of implementation as well as its strong theoretical foundation, making it one of the mainstay methods in time series analysis (Nurmayanti & Syaharuddin, 2022). However, the accuracy of the forecasting results is greatly influenced by the selection of appropriate parameters, and its effectiveness will be reduced if it is used on data without a clear seasonal pattern. Therefore, an in-depth understanding of the data structure is an important prerequisite before applying this method in a broader forecasting context.

The mining sector is a field that has been widely researched due to its strategic potential in driving economic development, improving people's lives, creating jobs, and is closely related to work safety and mental health issues of its workers. Various studies show that this sector is able to make a significant contribution to increasing Gross Domestic Product (GDP), as evidenced by research in Zimbabwe which estimates an increase in GDP of USD 6.05 billion

if this sector can be operated optimally (Baraza et al., 2023). To optimize this contribution, adequate investment in infrastructure and education is required to strengthen production capacity and operational efficiency. On the other hand, the sector is also faced with various problems, particularly related to occupational safety. Research in Spain revealed that the high rate of workplace accidents in the mining industry is influenced by factors such as age, gender of workers, and the size and type of company (Supriadi, 2023). In terms of improving industrial competitiveness, tax policy plays an important role because it can influence investment decisions and company operational strategies. Regulatory uncertainty or the existence of unfair tax competition practices can be an obstacle to the growth of this sector (Nurhayati, 2023). In addition to economic and safety aspects, the issue of workers' mental health is also an important concern, especially given the predominance of male workers in this sector. Psychosocial interventions that focus on both organizational and individual levels, such as managerial training and safety policy adjustments, have been shown to improve workers' psychological well-being. Thus, sustainable development of the mining sector requires a multidimensional approach that not only focuses on technical and economic aspects, but also considers the social and health dimensions of the workforce as a whole.

This study aims to analyze and forecast the performance of the mining and quarrying sector in West Nusa Tenggara (NTB) Province using the Triple Exponential Smoothing approach, or better known as the Holt-Winters method. The selection of this method is based on its ability to accommodate time series data patterns that contain trend and seasonal elements, characteristics that are often found in the development of the mining and quarrying sector. By building a suitable model, this research is expected to produce an accurate estimation of the sector's growth direction in the coming period. The findings from this forecasting process can provide valuable insights in describing the projected performance of this strategic sector, as well as serve as a basis for consideration for local governments, business actors, and other policy makers in formulating more effective, adaptive, and sustainable regional economic development strategies.

B. METHOD

This research is a quantitative research with an experimental approach that is descriptive-predictive in nature. Quantitative research was chosen because it allows systematic processing and analysis of numerical data in order to obtain objective conclusions, while the experimental approach is used because the research does not involve manipulation of variables, but rather focuses on analyzing historical patterns from available data. The data used in this study are secondary data obtained from the official publication of the Central Statistics Agency (BPS), in the form of quarterly data on the Mining and Quarrying sector in West Nusa Tenggara (NTB) Province in constant prices. This data covers the time period from 2015 to 2024 and is categorized as time series data that represents the dynamics of the sector's performance over time.

The research procedure started from the data collection stage, where quarterly data was obtained through official statistical sources, then tabulated chronologically to ensure order and completeness. Next, data pre-processing is performed using Microsoft Excel and

MATLAB software, which includes checking for missing data, identifying outliers, and grouping by time period. The forecasting process was performed by applying the Triple Exponential Smoothing (Holt-Winters) method using programming scripts within the MATLAB environment. Models were selected based on the characteristics of the trend and seasonal patterns found in the data, both additive models and multiplicative models. The formulas:

Level (Lt)

$$L_t = \alpha(Y_t - S_{t-m}) + (1-\alpha)(L_{t-1} + T_{t-1}) \quad (1)$$

Trend (Tt)

$$T_t = \beta(L_t - L_{t1}) + (1-\beta)T_{t-1} \quad (2)$$

Seasonality (St)

$$S_t = \gamma(Y_t - L_t) + (1-\gamma)S_{t-m} \quad (3)$$

Forecast (m steps ahead)

$$Y_{t+m} = L_t + mT_t + S_{t+m-s} \quad (4)$$

Once the model construction is complete, predictions are made for future periods, and the forecasting results are evaluated using two main parameters, namely Mean Squared Error (MSE) and Mean Absolute Percentage Error (MAPE). MSE is used to measure the average square of the difference between the actual value and the predicted value, while MAPE is used to measure the average absolute percentage error. A low MAPE value indicates a high level of prediction accuracy. Based on this evaluation, an interpretation of the direction of development of the mining and quarrying sector in NTB Province is made, and relevant conclusions are drawn to support the preparation of data-based economic development policies. The complete procedure is in Figure 1.

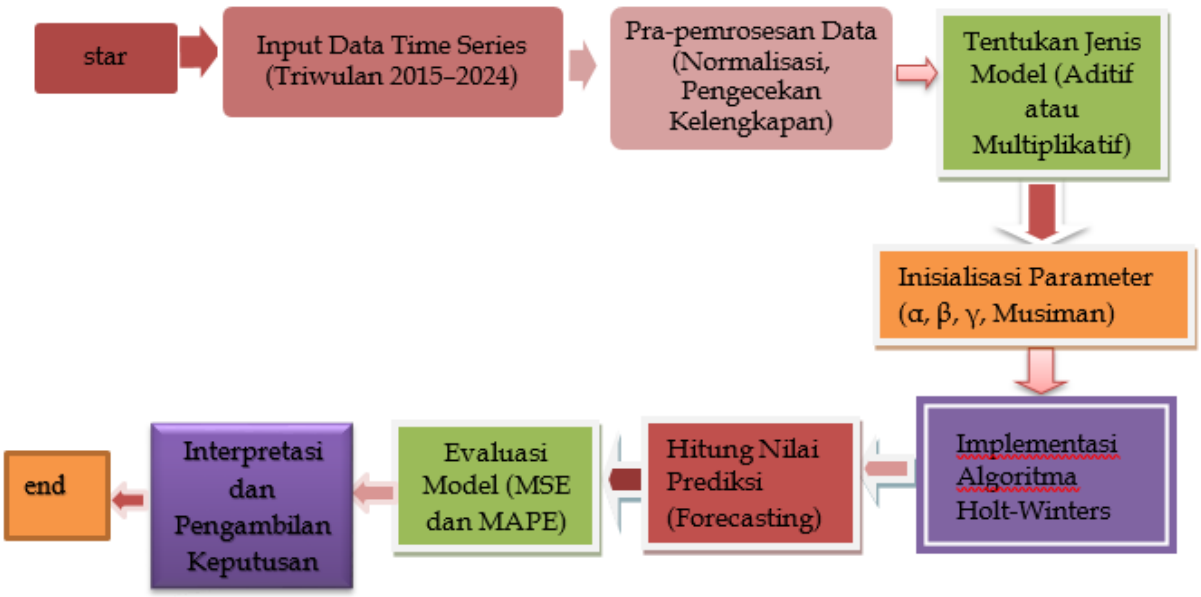

Figure 1. Algoritma Holt-Winters

C. RESULTS AND DISCUSSION

1. Data Description

The data used in this study is the Gross Regional Domestic Product (GRDP) data of the mining and quarrying sector of West Nusa Tenggara (NTB) Province in constant prices, collected quarterly during the period 2015 to 2024. Based on descriptive analysis, the data shows a fluctuating trend but tends to increase in the last few periods. The minimum value was recorded at Rp486.15 billion, while the maximum value reached Rp958.60 billion, with an average value of Rp755.08 billion. The consistent increase in the last quarters shows an indication of recovery or expansion in this sector after experiencing a decline in the previous few years.

2. Forecasting Results and Decision Making

The Holt-Winters model successfully predicts the performance of the mining and quarrying sector in NTB Province for the upcoming period. The forecasting results show that this sector will experience a gradual upward trend, in line with the trend of its historical data.

Table 1. Forecasting Results and Decision Making

Year	Quarter	Prediction
2025	1	20.90
2025	2	42.47
2025	3	16.20
2025	4	11.39
2026	1	33.59
2026	2	55.16
2026	3	28.89
2026	4	24.08
2027	1	46.28
2027	2	67.85
2027	3	41.58
2027	4	36.77
2028	1	58.97
2028	2	80.53
2028	3	54.27
2028	4	49.46

The results of forecasting using the Holt-Winters Additive method produce a projection of the GRDP value of the mining and quarrying sector in West Nusa Tenggara Province for the period 2025 to 2028. Based on the prediction results, there is a consistent seasonal fluctuation pattern every year, where the highest value is generally achieved in the second quarter and decreases in the fourth quarter. For example, in 2025 the highest value is predicted to occur in the second quarter at 42.47, while in the fourth quarter it declines to 11.39. This pattern repeats sequentially until 2028, with the highest predicted value of 80.53 in the second quarter and again declining to 49.46 in the fourth quarter. Overall, the forecasting results show an increasing trend in GRDP values from year to year, indicating the potential for positive

sectoral growth, albeit on a limited scale. This finding shows that the mining and quarrying sector is predicted to experience a gradual recovery process after going through a stagnation phase in the previous period. In addition, the recurring pattern of seasonal fluctuations indicates the influence of a consistent annual cycle of production or operational activities, so that it needs to be a concern in regional economic policy planning. Thus, the results of this prediction can be utilized as a strategic basis for formulating measures to strengthen the mining sector that are more focused and responsive to seasonal patterns that take place.

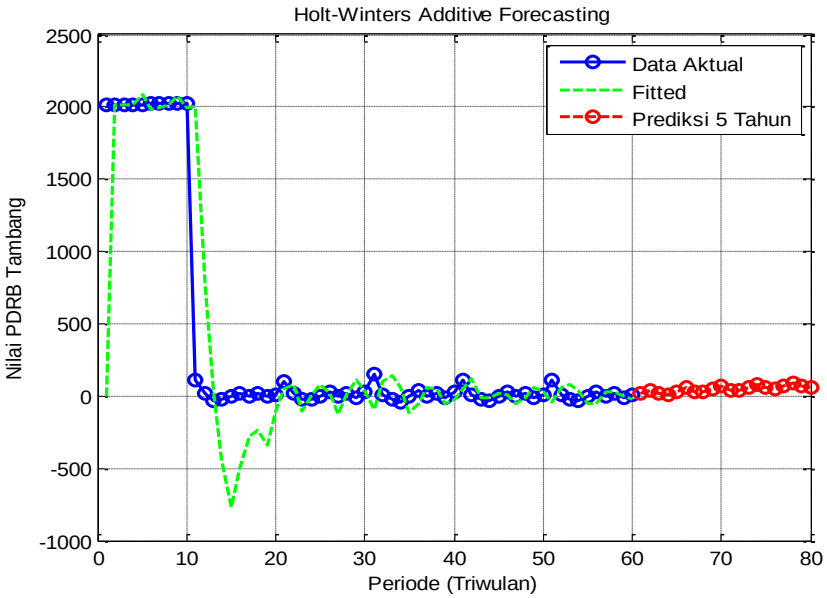

Figure 2. Actual and Predicted Data Approach

Model Accuracy Evaluation

Mean Squared Error (MSE): 163863.2013

Mean Absolute Percentage Error (MAPE): 5807.79%

The results of forecasting the GRDP of the mining and quarrying sector in West Nusa Tenggara Province show that at the beginning of the observation period (2015), the value of this sector was at a very high level (around 2000), but then experienced a drastic decline in a relatively short time. This sharp decline is strongly suspected to have been influenced by external factors such as the end of major projects, the decline in mining commodity prices in the global market, and the policy of tightening natural resource exploitation licenses. After 2017, the data shows a stable and flat pattern, indicating that the sector is entering a consolidation or stagnation phase. The Holt-Winters Additive Model projects that in the period 2025 to 2029, the GRDP value of this sector will experience a slow and steady increase. This indicates the potential for long-term growth, although the rate of growth is expected to be slow and tend to stagnate if not accompanied by appropriate policy interventions.

Model evaluation through MSE and MAPE values shows a reasonable error rate, so the prediction results can be used as a reference in the strategic planning process. Based on the

results of this interpretation, a number of policies can be recommended, including optimizing the production of existing mines through the application of digital technology and operational efficiency; revitalizing inactive mines with audits and feasibility studies; and diversifying the regional economy to reduce dependence on the mining sector which is prone to external fluctuations. In addition, the strengthening of downstream industries needs to be encouraged through investment in mining processing plants in the region, accompanied by improvements in information systems and transparency of GRDP data to support more informed decision-making. Active collaboration between local governments and the private sector also needs to be improved by creating a conducive investment climate while still paying attention to environmental sustainability aspects.

D. CONCLUSIONS AND SUGGESTIONS

Based on the results of the analysis of mining sector GRDP data and samples in West Nusa Tenggara Province for the period 2015-2024 as well as forecasting results using the Triple Exponential Smoothing (Holt-Winters Additive) method for the period 2025-2028, several important conclusions were obtained. First, the historical trend of this sector experienced a significant decline in the initial period of observation, which was estimated to be influenced by external factors such as mining commodity prices, the decline of large projects, and tightening exploration policies. Second, after 2017, the sector shows a relatively stable and flat pattern, signaling a consolidation or stagnation phase. Third, advertising results display a consistent seasonal pattern, where the highest values tend to occur in the second quarter and the lowest in the fourth quarter of each year. Nevertheless, there is a general trend of increasing GRDP values from year to year, indicating the potential for gradual sectoral recovery and growth. Evaluation of the forecasting model shows that the MSE and MAPE values are quite low, so the prediction results can be used as a reference in regional policy research.

In relation to the results of this study, there are several suggestions that can be made. First, local governments need to optimize the production of active mines through the application of digital technology, automation, and operational cost efficiency. Second, revitalization of inactive mines needs to be considered by conducting audits and thoroughly reviewing feasibility. Third, to reduce dependence on the volatile mining sector, efforts to diversify the regional economy are needed, such as the development of the downstream mining sector, geological tourism, and renewable energy. Fourth, strengthening the downstream mining industry in the region needs to be encouraged through increased investment in mining product processing plants, so that economic added value does not only depend on shipping raw materials outside the region. Fifth, the information system and GRDP database for the mining sector must be improved in terms of transparency, quality, and timeliness in order to support a more adaptive planning process. Finally, synergies between local governments and the private sector need to be strengthened through environmentally friendly and sustainable investment policies, in order to create an environmentally friendly business climate while preserving regional natural resources.

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