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ADDITIVE HOLT-WINTERS METHOD FOR FORECASTING GROSS REGIONAL DOMESTIC PRODUCT AT CONSTANT PRICES OF EXPENDITURE OF WEST SUMATRA

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ABSTRACT

Regional disparities often pose significant challenges, with some areas experiencing rapid economic growth while others lag behind. An essential macro benchmark to gauge the success of development initiatives is economic growth, as indicated by changes in a region's Gross Regional Domestic Product (GRDP). Using GRDP at constant prices (GRDP CP) helps eliminate the impact of price fluctuations, focusing on real increases in production activities. Expenditure GRDP reflects the value of goods and services produced within a region and consumed by the community. In the case of West Sumatra, the GRDP CP expenditure data reveals simultaneous seasonal and trend elements. The seasonal pattern, occurring quarterly each year, exhibits an additive seasonal effect. The Additive Holt-Winters method has been proven effective for data containing seasonal patterns with constant seasonal variation (additive) and linear trends, where the level, trend, and seasonal pattern can change. The data used is secondary data of GRDP CP of expenditure quarterly of West Sumatra in 2010 - 2022 obtained from the official website of the Indonesian Central Bureau of Statistics. According to research findings, the GRDP CP expenditure with a Mean Absolute Percentage Error (MAPE) value of 1.03% for quarter I to quarter IV in 2023 are Rp46,284,010.59, Rp46,472,223.99, Rp47,512,197.79, and Rp48,445,184.94, respectively. This suggests that the model equation performs exceptionally well predicting future economic trends.

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1. INTRODUCTION

Regional disparities pose a significant and persistent challenge, with certain areas witnessing robust economic growth while others grapple with slower development. The uneven progress across regions is primarily attributed to disparities in available resources. Capital, largely driven by investor decisions, tends to gravitate towards urban areas or regions already equipped with essential facilities, including robust transportation infrastructure, electricity networks, telecommunications systems, banking and insurance services, and a skilled labor force. This capital concentration exacerbates existing inequalities in income redistribution from the central government to the various regions. Addressing these disparities requires a comprehensive approach, acknowledging the multifaceted nature of the issue. Strategies should encompass not only economic considerations but also factors such as equitable resource allocation, infrastructure development, and a fair redistribution of income to foster inclusive and sustainable growth across all regions [1].

One indicator of the success of development implementation that can be used as a macro benchmark is economic growth, which is reflected in changes in Gross Regional Domestic Product (GRDP) in a region. GRDP is defined as the amount of added value generated by all business units in a region or is the total value of final goods and services produced by all economic units in a region [2]. The realization of regional economic growth can be measured using an increase in the value of GRDP at Constant Prices (GRDP CP) from one period to another. GRDP CP avoids calculating price increases because regional economic growth is basically an increase in production activities in real terms (excluding price increases), both in the form of goods and services, within a certain period [3].

The magnitude of the GRDP value of a region can be calculated through three types of approaches: the production approach, the expenditure approach, and the income approach. In this study, the GRDP approach used is expenditure GRDP. Expenditure GRDP explains the value of goods and services (output) produced in the domestic area used as "final" consumption by the community. Specifically, what is meant by final consumption is the use of goods and services that are not intended for further processing (consumed out). The use of the final product is realized in the form of final demand. The final demand consists of the components of Household Final Consumption Expenditure (POES), Final Consumption Expenditure of Non-Profit Institutions Serving Households (NPISHs), Government Final Consumption Expenditure (GFCE), Gross Fixed Capital Formation (GFCF), Change in Inventory (CI), as well as the export component of goods and services [4].

From 2010 to 2022, an overview of the economic development of West Sumatra Province based on GRDP CP of expenditure can be seen, presented in quarterly form. For certain quarters of every year, West Sumatra's GRDP CP value of expenditure shows an increase from year to year per quarter except in 2020 due to the COVID-19 pandemic, and from 2021 to 2022, it increases again. Hence, the data exhibit seasonality, with the most significant seasonal effect always happening in every fourth quarter and the smallest seasonal effect always happening in every first quarter. Seasonality is the tendency of time series data to exhibit behavior that repeats every *t* period [5]. The data also show a linear trend as it tends to get higher for the same quarter as time goes by. It can be noted that the amplitude of the seasonal pattern, that is, the range of the periodic behavior within a year per quarter, remains more or less constant in time and remains independent of the average level within a year per quarter.

Many problem-solving analyses using GRDP data have been conducted, including forecasting. Forecasting is the prediction of future events [6]. If the time series data used for forecasting contains trend and seasonal elements, it can be used as a model covering both aspects. This is due to the weakness of some forecasting models that only cover the trend element but cannot cover the seasonal pattern of the time series data [7]. Because the data of GRDP CP of expenditure of West Sumatra has aspects of seasonality and trend, the forecasting method that can be used is the Holt-Winters method. The Holt-Winters method is based on three smoothing equations: one for level, one for trend, and one for seasonality. There are two different Holt-Winters methods, depending on whether seasonality is modeled in an additive or a multiplicative way. In this study, the additive Holt-Winters method was used. In the additive model, the seasonal fluctuations of the data appear relatively stable, independent of the level or average of the time series [8]. The results of this analysis will be significant, meaning that it is one of the inputs for local governments and related authorities in formulating regional development policies or preparing development plans for the area concerned [9]. These economic decisions aim to influence, direct, and sometimes even control the level and growth of critical

financial variables (income, consumption, employment, investment, savings, exports, imports, etc.) to fulfill predetermined development goals [10].

Several studies have been conducted using the Holt-Winters method, one of which is by [11] with the title "Implementation of Holt-Winters Exponential Smoothing for Forecasting Food Prices in Pamekasan Regency" with the conclusion that the multiplicative model and additive model produce MAPE values below 10%. Although similar, the additive model has better accuracy than the multiplicative model because it has a smaller MAPE value. Then other research using the Holt-Winters method conducted by [12] with the title "Forecast Number of Passengers Using Exponential Smoothing Holt-Winters (Case Study: number of departure passengers on international flights at Soekarno Hatta airport in January 2006 - December 2008) with the conclusion that the Exponential Smoothing Holt-Winters additive model has a smaller forecast accuracy value than the Exponential Smoothing Holt-Winters multiplicative model with a MAPE value of 5.62%. Furthermore, research conducted by [13] using the additive Holt-Winters method with the title "Implementation of the Holt Winter Additive Method for Predicting Nusantara Tourist Visits in Sumenep Regency" with the conclusion that the SMAPE forecasting accuracy value obtained is 13.65%, which is included in the accurate category in forecasting tourist visit data in Sumenep Regency.

2. RESEARCH METHODS

The data used is secondary data of GRDP CP of expenditure quarterly of West Sumatra in 2010 - 2022 obtained from the official website of the Indonesian Central Bureau of Statistics. In forming a forecasting model of GRDP CP of expenditure quarterly of West Sumatra in 2010 - 2022 using the additive Holt-Winters method, the steps are as follows:

1. Dividing data into initialization set and test set. In this case the length of seasonal (s) is 4.
2. Initializing the set of the level and seasonal using 2010 data only while initializing the set of the trend using data from 2010 to 2011.
3. Optimizing the values of parameters and forecasting the test set using data from 2011 to 2022.
4. Testing error measurement with evaluation models.
5. Deciding on the forecasting result.

2.1 Gross Regional Domestic Product (GRDP)

Gross Regional Domestic Product (GRDP) is primary data and information about the economic activities of a region. GRDP is the sum of the production value of goods and services produced in an area in a certain period. This GRDP data is available in almost all provinces, districts, and cities in Indonesia and is published by the local statistics center annually. Analysis and development planning related to the regional economy, such as the structure of the regional economy, economic growth, and the level of regional prosperity, generally use this GRDP as basic data and information [3].

GRDP values are differentiated based on current price and constant price. GRDP at current prices shows the value added of goods and services calculated using prices prevailing in each year and is used to see the movements and structure of the economy. Meanwhile, GRDP at constant prices shows the value added of goods and services calculated using prices in a particular year as a basis and is used to determine economic growth in a period to a period (year to year or quarter to quarter) [4].

In this study, the value of GRDP used is based on constant prices (GRDP CP). GRDP CP is used to determine economic growth from period to period (year to year or quarter to quarter). Three approaches are usually used in calculating GRDP, namely the production approach, the income approach, and the expenditure approach. The expenditure approach is used in this study. According to the expenditure approach, GRDP is all components of final demand consisting of Household Final Consumption Expenditure (HFCE), Final Consumption Expenditure of Non-Profit Institutions Serving Households (NPISHs), Government Final Consumption Expenditure (GFCE), Gross Fixed Capital Formation (GFCF), Change in Inventory (CI) and import-export [14].

2.2 Time Series Forecasting

Forecasting is the prediction of future events. Forecasting is a critical problem covering many fields, including business and industry, government, economics, environmental science, medicine, social science, politics, and finance. Forecasting techniques are divided into two main categories: quantitative and qualitative. Quantitative methods can be divided into time series and causal methods, while qualitative methods can be divided into exploratory and normative [15]. In this research, the forecasting technique used is the quantitative time series method. Quantitative forecasting techniques use historical data formally and forecasting models [6].

2.3 Holt-Winters Method

Holt-Winters triple exponential smoothing is a recent method named after its founders, Charles Holt and Peter Winters. It helps find patterns of level changes, trends, and seasons over time using additive or multiplicative seasons [16]. The Holt-Winters technique is a complex extension of the exponential smoothing method, as it summarizes this approach to managing trends and seasonality [17]. This method is divided into two parts: the multiplicative seasonal method, used for seasonal variations in data that experience increases/decreases (fluctuations), and the additive seasonal method, used for constant seasonal variations [18]. In this research, we used the additive Holt-Winters method.

2.4 Additive Holt-Winters Method

The additive seasonal model is used when the time series data exhibits additive seasonality [19]. Forecasting methods in the additive model, the seasonal fluctuations of the data appear relatively stable, independent of the level or average of the time series [6]. The initial values of the components are required to start the calculation. To initialize the additive Holt-Winters method, we need initial values of the level (L_t), trend (b_t), and seasonal components (S_t) are required. To determine initial estimates of the seasonal components, we need to use at least one complete season's data. Therefore, we initialize the trend and level at period s [15].

The initialization equations of the additive Holt-Winters method with the initial values of the level (L_t) as L_s, trend (b_t) as b_s, and seasonal components (S_t) as S_s are as follows [15]:

Level initialization

$$L_s = \frac{1}{s}(Y_1 + Y_2 + \cdots + Y_s) \tag{1}$$

Trend initialization

$$b_s = \frac{1}{s}\left[\frac{Y_{s+1}-Y_1}{s} + \frac{Y_{s+2}-Y_2}{s} + \cdots + \frac{Y_{s+s}-Y_s}{s}\right] \tag{2}$$

Seasonal initialization

$$S_1 = Y_1 - L_s, S_2 = Y_2 - L_s, \ldots, S_s = Y_s - L_s \tag{3}$$

Where:

s : seasonal length

L_s : level smoothing at s

b_s : trend smoothing at s

S_s : seasonal smoothing at s

The basic equations of the additive Holt-Winters method are as follows [15]:

Level

$$L_t = \alpha(Y_t - S_{t-s}) + (1-\alpha)(L_{t-1} + b_{t-1}) \tag{4}$$

Trend

$$b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1} \quad (5)$$

Seasonal

$$S_t = \gamma(Y_t - L_t) + (1-\gamma)S_{t-s} \quad (6)$$

Forecasting

$$F_{t+m} = L_t + b_t m + S_{t-s+m} \quad (7)$$

Where:

α: level smoothing parameter, $0 \leq \alpha \leq 1$

β: trend smoothing parameter, $0 \leq \beta \leq 1$

γ: seasonal smoothing parameter, $0 \leq \gamma \leq 1$

s: seasonal length

m: the number of future periods to be forecasted

Y_t: actual data at period t

L_t: level smoothing at period t

b_t: trend smoothing at period t

S_t: seasonal smoothing at period t

F_{t+m}: forecasting at period $(t+m)$

2.5 Evaluation Model

The accuracy of the prediction model will be evaluated using Mean Absolute Percentage Error (MAPE). MAPE is used to calculate error rates or error values that happen when performing a forecasting process. The use of MAPE also calculates the average value of the error of the forecasting results in percent. If the MAPE result is lower, the forecasting results' accuracy is better **[20]**.

The MAPE equation can be seen in **Equation (8) [20]**.

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{|Y_t - F_t|}{Y_t}\right| \times 100\% \quad (8)$$

Where:

Y_t: actual data at period t

F_t : forecasting result at period t

n : total data used

The following are the criteria for evaluation using MAPE can be seen in **Table 1**.

Table 1. MAPE Value Criteria

MAPE Value	Criteria
<10%	Very Good
10% - 20%	Good
20% - 50%	Pretty Good
50%	Bad

3. RESULTS AND DISCUSSION

3.1 Descriptive Statistics

The first step in exploring the data conducted in this study is to create a time series plot of the research data. Time series plots are used to see the pattern of the data. The following are the results of the time series plot and the GRDP CP trend of West Sumatra expenditure data in 2010 - 2022.

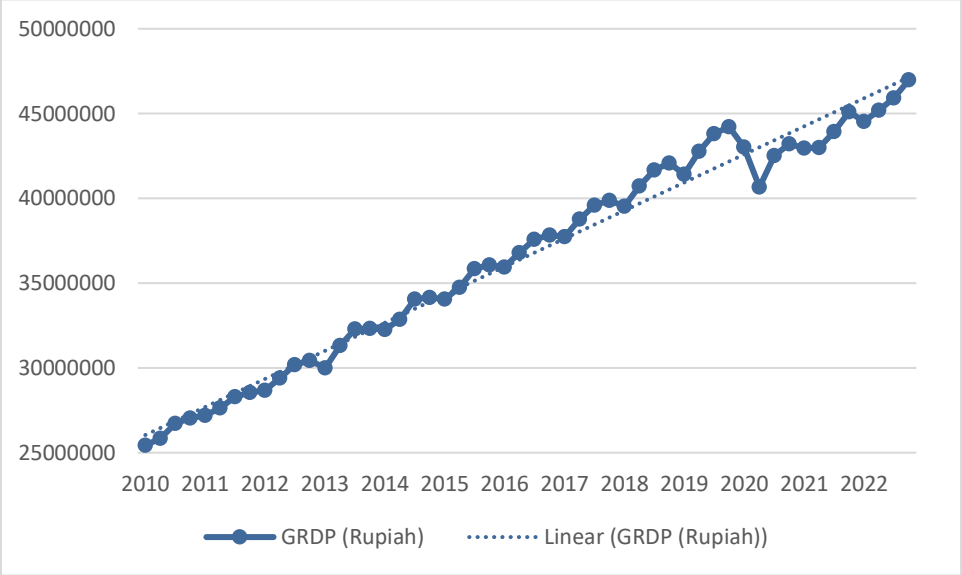

Figure 1. Plot of GRDP CP of expenditure quarterly of West Sumatera 2010 - 2022

Based on **Figure 1**, the GRDP CP of expenditure of West Sumatra shows a regular fluctuation pattern that almost always occurs every year per quarter. The most considerable seasonal effect always appears in every fourth quarter. So, every fourth quarter, there is a phenomenon that causes West Sumatra's GRDP CP of expenditure figure to be greater than that of other quarters. Descriptive statistics of GRDP CP of expenditure of West Sumatra for more details can be seen in **Table 2**.

Table 2. Descriptive Statistics

Variable	Mean	Std. Deviation	Min	Max
GRDP CP of expenditure of West Sumatra (Rupiah)	35,995,813.25	6,334,673.81	25,434,215.93	46,985,822.13

Based on **Table 2**, it can be concluded that the lowest number of GRDP CP of expenditure of West Sumatra of Rp25,434,215.93 occurred in the first quarter of 2010, and the highest number of GRDP CP of expenditure of West Sumatra of Rp46,985,822.13 happened in the fourth quarter of 2022. The average GRDP CP expenditure in West Sumatra amounted to Rp35,995,813.25 per quarter per year, with a standard deviation of Rp6,334,673.81.

In general, West Sumatra's GRDP CP of expenditure always follows an upward trend pattern. This means that the amount of GRDP CP of expenditure in West Sumatra always grows from time to time, although in 2020, it decreased due to the COVID-19 pandemic, which then experienced an increase again in the following year. GRDP CP of expenditure of West Sumatra's data contains seasonal and trend elements simultaneously. The seasonal pattern that occurs each year per quarter is an additive seasonal effect. This additive seasonal effect is indicated by seasonal fluctuations from year to year per quarter of almost the same magnitude.

3.2 Initialization

The initial component values are required to start the calculation. The initialization equations of the additive Holt-Winters method with the initial values of the level (L_t) as L_s, trend (b_t) as b_s, and seasonal components (S_t) as S_s are as follows.

Table 3. Initialization Value

Year	Quarter	t	GRDP CP of Expenditure (Rupiah)	L_s	b_s	S_s
2010	1	1	46,284,010.59			-820,218.94
	2	2	46,472,223.99			-421,355.60
	3	3	47,512,197.79			471,402.24
	4	4	48,445,184.94	26,254,434.87	416,359.60	770,172.28
Year	**Quarter**	**t**	**GRDP CP of Expenditure (Rupiah)**	L_s	b_s	S_s
2011	1	5	27,186,414.92			
	2	6	27,638,612.69			
	3	7	28,311,612.82			
	4	8	28,542,852.55			

Table 3 is the process of calculating the initial values of the level (L_s), trend (b_s), and seasonal components (S_s) where s = 4 using **Equation (1)**, **Equation (2)**, and **Equation (3)**.

3.3 Optimizing Parameters

Determination of the parameter values of the Holt-Winters method is sought for the weighting values or parameters α, β and γ. These parameters help calculate the predictive value of the Holt-Winters method. The parameters are chosen with a value between 0 and 1 with the smallest error value; if it is close to 1, the latest forecast result will include an error adjustment to the previous data. If it is close to 0, the latest forecast will consist of a minor adjustment.

Due to much faster computation, it is relatively easy to select the optimal values of the parameters using non-linear optimization algorithms automatically by minimizing MAPE. The algorithm and method used by Solver in Microsoft Excel is the GRG Nonlinear Solving Method for nonlinear optimization using the Generalized Reduced Gradient (GRG2) code with the following formula programs **[21]**:

$$\text{minimize } g_{m+1}(X)$$

$$\text{subject to } g_i(X) = 0,\ i = 1, \text{neq},$$

$$0 \le g_i(X) \le ub(n+i),\ i = \text{neq} + 1, m,$$

$$lb(i) \le X_i \le ub(i),\ i = 1, n$$

Where X is a vector of n variables, the number of equality constraints, neq, may be zero; the functions g_i are assumed differentiable.

By using Solver in Microsoft Excel, the best parameters are α = 0.29; β = 0.05 and γ = 0.51 with a MAPE value of 1.03% are automatically obtained.

3.4 Forecasting

Before forecasting the GRDP CP of expenditure of West Sumatra for the first quarter to fourth quarter of 2023, smoothing of the level (L_t), trend (b_t), and seasonal components (S_t) are performed.

Table 4. Smoothing Value

Year	Quarter	t	GRDP CP of Expenditure (Rupiah)	L_t	b_t	S_t
2010	1	1	46,284,010.59			-820,218.94
	2	2	46,472,223.99			-421,355.60
	3	3	47,512,197.79			471,402.24
	4	4	48,445,184.94	26,254,434.87	416,359.60	770,172.28
2011	1	5	27,186,414.92	27,056,431.12	437,302.06	-336,337.99
	2	6	27,638,612.69	27,657,196.70	446,179.15	-216,248.32
	3	7	28,311,612.82	28,027,404.01	442,053.40	376,075.92
	4	8	28,542,852.55	28,268,308.38	431,129.76	517,778.78
	⋮	⋮	⋮	⋮	⋮	⋮
2022	1	49	44,523,670.12	45,000,173.05	365,614.83	-520,758.48
	2	50	45,188,924.44	45,609,112.46	378,828.87	-714,422.37
	3	51	45,931,125.81	45,987,719.67	378,816.83	-56,325.83
	4	52	46,985,822.13	46,422,891.80	381,877.27	494,784.04

Table 4 is the process of calculating smoothing of the level (L_t), trend (b_t), and seasonal components (S_t) using **Equation (4)**, **Equation (5)**, and **Equation (6)**.

The following is a table and figure of the forecasting results:

Table 5. Forecasting GRDP CP of Expenditure Quarterly of West Sumatra 2023

Year	Quarter	t	Forecasting of GRDP CP of Expenditure (Rupiah)
2023	1	53	46,284,010.59
	2	54	46,472,223.99
	3	55	47,512,197.79
	4	56	48,445,184.94

Table 5 is the process of calculating forecasting using **Equation (7)**. Based on **Table 5**, West Sumatra's GRDP CP of expenditure has increased every quarter. The first step is to look at the forecasting results.

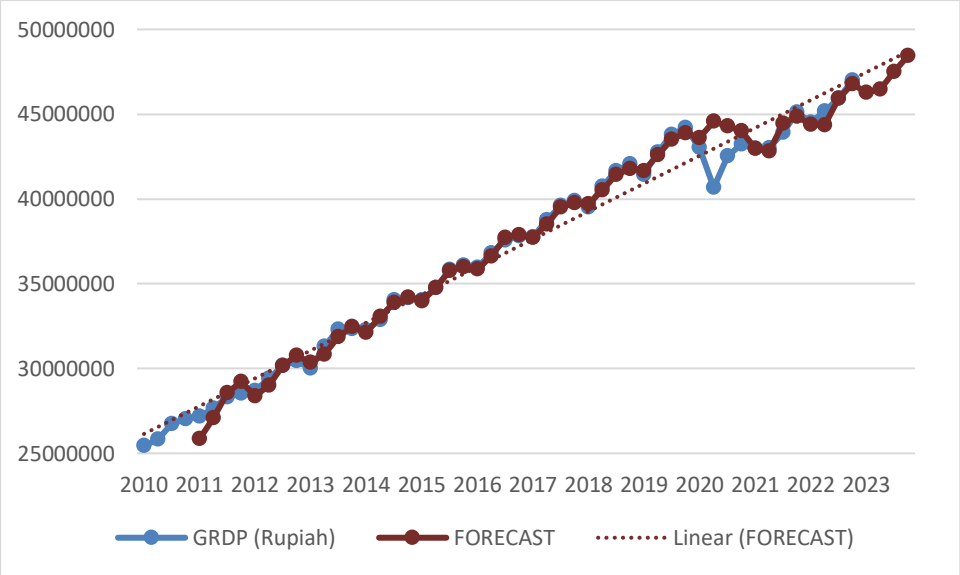

Figure 2. Plot of Forecasting GRDP CP of expenditure quarterly of West Sumatra 2023

Based on **Figure 2**, the forecasting and actual data of GRDP CP on expenditure in West Sumatra are almost the same. The forecasting results show an increase for the following few periods in 2023 with a MAPE value of 1.03%, which means that the forecasting equation model for GRDP CP of expenditure of West Sumatra is very good.

3.5 Discussion

Based on the forecasting results in **Table 5** and **Figure 2**, West Sumatra's GRDP CP of expenditure has increased every quarter. The first step is to pay attention to the forecasting results. **Figure 2** shows that the forecasting data and the actual data of GRDP CP of expenditure of West Sumatra are almost the same, and the forecasting results show an increase for the following few periods in 2023.

The Holt-Winters method can be used to forecast the GRDP CP of expenditure in West Sumatra. The process was carried out to calculate the forecast of GRDP CP of expenditure of West Sumatra by determining the parameter values α, β, γ by using Solver in Microsoft Excel. In this study the value of $\alpha = 0.29$; $\beta = 0.05$ and $\gamma = 0.51$ with a MAPE value of 1.03%.

Based on the model obtained, the forecast of GRDP CP of expenditure of West Sumatra for the upcoming period is determined with the following equation model:

$$F_{t+m} = 46{,}422{,}891.80 + 381{,}877.27(m) + S_{t-s+m}$$

where *t* is the previous data period, *m* is the period ahead to be forecasted, and *s* is the length of the seasonal.

4. CONCLUSIONS

The data on expenditure in West Sumatra from GRDP CP has elements of the Holt-Winters method, namely trend and seasonality. Seasonal patterns are stable, so the additive type of the Holt-Winters method can be used. In the forecasting results, the value of the MAPE model evaluation is 1.03%, where the results obtained are very good because they are below the 10% value. Based on forecasting results, the highest increase occurred in the fourth quarter, which indicates that there will be a phenomenon that makes the fourth quarter more significant than the other quarters.

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