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Energy and Economic Growth In Northern Sumatra

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ABSTRACT

This study analyzes the influence of energy, unemployment, infrastructure, government expenditure, and investment on economic growth in the Northern Sumatra region (SUMBAGUT), which includes Aceh, North Sumatra, West Sumatra, Riau, and the Riau Islands. The study employs panel data from 2005 to 2024 and applies the Panel ARDL model to capture both short- and long-term relationships among variables. The estimation results indicate that, in the long run, energy, infrastructure, and government expenditure exert a suppressing effect on economic growth in the SUMBAGUT region. In the short term, energy, unemployment, infrastructure, government expenditure, and investment do not show statistically significant effects on economic growth. These findings suggest that economic growth in SUMBAGUT is strongly influenced by the quality of energy utilization, the effectiveness of infrastructure development, and the efficiency of government expenditure. The long-term suppressing effects of these variables reflect potential inefficiencies and resource misallocation. Moreover, the absence of significant short-term effects indicates that development policies require time to generate measurable impacts on economic activity. Therefore, more effective and efficient development policies are necessary to promote sustainable economic growth in the SUMBAGUT region.

Keywords: Unemployment, Economic growth, Energy, Infrastructure, Government expenditure, GFCF, Panel ARDL

INTRODUCTION

Economic growth constitutes a long-term macroeconomic concern due to its tendency to develop at rates below its optimal potential, thereby exerting a negative impact on the overall economy (Wahyudi & Silpayana, 2022). In the context of Indonesia, Sumatra Island holds a strategically significant position as the second-largest contributor to the national Gross Domestic Product (GDP), reinforced by its abundant natural resources and the diverse economic characteristics present across its provinces (Mardhian et al., 2023). The economic output of Sumatra is primarily driven by several key provinces, including North Sumatra, Riau, and South Sumatra (BPS Indonesia, 2023), with trade activities chiefly concentrated in the city of Medan (Yuslinaini et al., 2015).

Generally, the dynamics of economic growth in Sumatra and the SUMBAGUT region exhibit distinct characteristics shaped by their respective economic structures. The provinces of Riau and North Sumatra experienced the highest economic growth, attributable to diversification within the processing and energy industrial sectors, thereby rendering them more resilient to external economic shocks (He et al., 2022). High energy consumption, especially in West Sumatra, underscores the crucial role of energy in fostering productivity and regional economic activity (Pasaribu et al., 2023).

Conversely, elevated unemployment rates in Aceh and West Sumatra are negatively correlated with economic growth, consistent with Okun's Law, which posits that a reduction in unemployment corresponds to an increase in economic output (Utari, 2025). From an infrastructural

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perspective, West Sumatra has made considerable contributions through the development of the transportation and warehousing sectors, thereby mitigating logistics costs and enhancing regional competitiveness (Ansofino, 2024). The relatively substantial government expenditure in Aceh, supported by the Aceh Special Autonomy Fund, facilitates infrastructure development and improvements in public services, thereby stimulating economic activity (Saputra et al., 2024).

Additionally, investments in the Riau Archipelago significantly bolster growth by augmenting production capacity and expanding the industrial and energy sectors (Ariyanto et al., 2024). Table 1 presents the average economic growth, energy consumption, unemployment rates, infrastructure development, government expenditure, and investment levels on Sumatra Island spanning the years 2005 to 2024 (percent).

Table 1 Average Economic Growth, Energy, Unemployment, Infrastructure, Government expenditure, and Investment in the SUMBAGUT Region from 2005-2024 (percent)

Province	Indicator					
	Economic Growth	Energy	Unemployment	Infrastructure	Government Expenditure	Investment
Aceh	1,37	1,61	8,29	7,17	19,19	29,26
Sumatera Utara	5,08	1,82	7,14	5,54	5,39	28,83
Sumatera Barat	1,59	1,95	7,33	12,00	8,50	28,04
Riau	5,68	0,66	6,84	0,99	3,41	29,32
Kepulauan Riau	1,54	1,74	7,81	3,18	4,68	41,23
Average	**2,23**	**1,54**	**6,34**	**5,42**	**8,62**	**30,87**

Source: Statistics of Indonesia, 2005-2024.

Overall, the SUMBAGUT region demonstrates relatively strong economic growth and infrastructure development performance. However, the persistently high unemployment rate indicates that such growth has not been fully inclusive. Variations in empirical findings on the impact of energy and infrastructure on economic growth across previous studies (Rezitis & Ahammad, 2015; Buhaerah, 2016; Sari, 2025; Lestari, 2025) further underscore the importance of this research. Therefore, this study focuses on the SUMBAGUT region to gain a deeper understanding of its regional development dynamics, thereby providing more relevant, context-specific policy implications.

METHODS

This research is a development economics study that analyzes the influence of energy, unemployment, infrastructure, government expenditure, and investment on economic growth in the Northern Sumatra region (SUMBAGUT). The study adopts a quantitative approach using secondary panel data covering the period 2005–2024, sourced from the Central Statistics Agency (BPS). The area of analysis is focused on SUMBAGUT, comprising five provinces: Aceh, North Sumatra, West Sumatra, Riau, and the Riau Islands. Concentrating on this region aims to capture regional economic development dynamics in a more specific and contextual manner, thereby providing relevant empirical evidence for regional policy formulation.

In this study, economic growth is employed as the dependent variable, while energy, unemployment, infrastructure, government expenditure, and investment serve as independent

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variables. The analysis is conducted using the Panel Autoregressive Distributed Lag (ARDL) model, which is suitable for data with mixed orders of integration. This approach allows the identification of both short-term and long-term relationships among variables within the economic dynamics of the SUMBAGUT region, thereby capturing differences in economic dynamics between the aggregate region and the more specific subregion.

$$\Delta EGDP_{i,t} = \beta_0 + \sum_{j=1}^{n1} \beta_{1i} \Delta \mathrm{EGDP}_{j,t-i} + \sum_{j=1}^{n2} \beta_{2i} \Delta \mathrm{lnENRG}_{j,t-i} + \sum_{j=1}^{n3} \beta_{3i} \Delta \mathrm{UNEMP}_{j,t-i} + \sum_{j=1}^{n4} \beta_{4i} \Delta \mathrm{INFRA}_{j,t-i} + \sum_{j=1}^{n5} \beta_{5i} \Delta \mathrm{lnGE}_{j,t-i} + \sum_{j=1}^{n6} \beta_{6i} \Delta \mathrm{INVEST}_{i,t-i} + \theta_1 EGDP_{j,t-1} + \theta_2 lnENRG_{j,t-1} + \theta_3 UNEMP_{j,t-1} + \theta_4 INFRA_{j,t-1} + \theta_5 lnGE_{j,t-1} + \theta_6 \mathrm{INVEST} + I_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The specification and interpretation of the indicators operationalized in this model are explained as follows. EGDP represents economic growth in the SUMBAGUT region. ENRG denotes energy consumption, UNEMP unemployment, INFRA infrastructure, GE government expenditure, and INVEST investment, all measured within the SUMBAGUT region. The coefficients β_1, β_2, β_3, and β_4 represent the short-term parameters of the model, while θ_1, θ_2, θ_3, and θ_4 denote the long-term coefficients. The symbol *t* indicates the observation period from 2005 to 2024. The index *j* represents the regions within the SUMBAGUT area, namely Aceh, North Sumatra, West Sumatra, Riau, and the Riau Islands. The index *i* denotes the lag order used in the estimation, and *e* represents the error term capturing other factors outside the model that may influence economic growth.

The short-term coefficients $\beta_{1,i}, \beta_{2,i}, \beta_{3,i}, \beta_{4,i}, \beta_{5,i}$ represent the impact of changes (Δ) in each independent variable energy, unemployment, infrastructure, government expenditure, and investment on economic growth in the short term. Estimation is conducted over several lags (i) to capture the delayed response of economic growth to changes in these variables. The long-term coefficients $\theta_1, \theta_2, \theta_3, \theta_4, \theta_5$ reflect the long-term equilibrium relationship between economic growth and all explanatory variables, by including the variables from the previous period (t−1) to identify long-term structural impacts.

In this study, economic growth is proxied through the Regional Gross Domestic Product (RGDP) transformed into natural logarithm form. This transformation aims to reduce scale differences among variables, stabilize variance, and minimize potential violations of the normality assumption. Using a logarithmic approach, the estimation results can be interpreted in terms of relative changes, making comparisons of influences between variables more proportional.

The ARDL panel model is used to analyze how the dynamics of energy, unemployment, infrastructure, government expenditure, and investment affect economic growth in Sumatra Island and North Sumatra (SUMBAGUT) during the period 2005–2024. This approach allows for the evaluation of short-term impacts that are temporary as well as long-term influences that are cumulative, thereby providing a more comprehensive picture of the mechanisms of regional economic growth and their implications for the formulation of sustainable development policies

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RESULTS AND DISCUSSION

RESULT

Stationary Test

The stationarity test is conducted to ensure that the data used does not produce spurious correlations and satisfies the requirements for applying the panel ARDL model, namely that the variables are integrated at the I(0) or I(1) level. This study employs the Phillips–Perron (PP) test, as it is considered more robust to issues of heteroskedasticity and autocorrelation than the ADF or Levin methods. The stationarity test is performed on the SUMBAGUT regional to capture the differences in data characteristics between regions and ensure the validity and consistency of the model used. Table 2 shows the differences in the results of the stationarity test, so the resulting model is an ARDL panel.

Table 2 Stationary Test for the SUMBAGUT Region

Variable	Level		First Difference		Integration Sequence
	Statistic	P-Value	Statistic	P-Value	
Economic Growth	117.872	0.2995	494.705	0.0000	I(1)
Energy	374.911	0.0000	352.595	0.0000	I(0)
Unemployment	265.352	0.0031	539.950	0.0000	I(0)
Infrastructure	449.516	0.0000	575.331	0.0000	I(0)
Government Expenditure	164.199	0.0882	517.798	0.0000	I(1)
Investment	234.059	0.0093	657.088	0.0000	I(0)

Source: Estimated Results, 2026.

Cointegration Test

After the data meet the statistical criteria, the analysis continues with the Pedroni cointegration test to identify the existence of long-term relationships between variables, including variables that previously did not show strong significance. The results of the Pedroni cointegration test in the SUMBAGUT region indicate a long-term relationship among the research variables. Within the dimension, the Panel PP and Panel ADF statistics are significant at the 5 percent level, so the null hypothesis of no cointegration can be rejected. These findings indicate a significant long-term relationship between economic growth, energy, unemployment, infrastructure, government expenditure, and investment in the SUMBAGUT region.

In the between-dimension, although not all indicators are significant, the Panel PP-statistic results provide strong evidence of cointegration. Overall, these results confirm the presence of partial but stable cointegration among economic variables in SUMBAGUT. These findings provide an empirical basis for continuing the analysis using the ARDL panel model to examine short-term dynamics and the adjustment process toward long-term equilibrium.

Table 3 Cointegration Test for the SUMBAGUT Region

Common AR Coefficients (within-dimension)	Statistic	Prob.	Statistic	Prob.
Panel v-statistic	-0.796258	0.7871	-0.860230	0.8052
Panel rho-statistic	0.654221	0.7435	0.791009	0.7855

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Panel PP-statistic	-2.184803	0.0145	-2.446274	0.0072
Panel ADF-statistic	0.915833	0.8201	-0.121839	0.4515

Common AR Coefficients (within-dimension)	**Statistic**	**Prob.**
Panel rho-statistic	1.481055	0.9307
Panel PP-statistic	-4.207113	0.0000
Panel ADF-statistic	0.760563	0.7765

Source: Estimated Results, 2026.

Selection of the Optimum Lag

The determination of the optimal lag in the ARDL panel model is carried out to ensure that dynamic relationships between variables are accurately represented and to avoid overfitting. As shown in Figure 1 of the Akaike Information Criterion (AIC), the estimation results indicate that the ARDL(1,1,1,1,1,1) model is the most optimal and consistent specification for SUMBAGUT, as it has the lowest AIC value among the alternative models. Thus, this model is chosen as the best because it can reliably and stably depict the short- and long-term relationships among economic growth, energy, unemployment, infrastructure, government expenditure, and investment in both regions.

Short-Term ARDL Estimation

The Error Correction Model (ECM) is used to explain how quickly economic variables adjust back to long-term equilibrium after a shock occurs. The error correction term (ECT) coefficient with a negative value indicates a process of adjustment toward equilibrium, where a coefficient value closer to -1 signifies a faster adjustment, while a value closer to 0 reflects a slower adjustment process.

Table 4 Short-Term Estimation Test Results for the SUMBAGUT Region

Variable	Coefficient	Std. Error	t-statistic	Prob.*
COINTEQ01	-0.277474	0.136076	-2.039103	0.0459
Energy	0.045056	0.095423	0.472173	0.6385
Unemployment	-0.012753	0.043698	-0.291839	0.7714
Infrastructure	-0.113025	0.089949	-1.256548	0.2138
Government Expenditure	-0.022706	0.032624	-0.695998	0.4891
Investment	-0.002497	0.010141	-0.246220	0.8064

*Note: * significance at the 5 percent level*
Source: Estimated Results, 2026.

The estimation results in Table 4 indicate that the Error Correction Model (ECM) coefficient is negative and statistically significant, suggesting that the ARDL panel model is suitable for the analysis. The ECM value of -0.2774 indicates a process of adjustment toward long-term equilibrium, with an adjustment period of approximately four months following a shock. In the short term, the variables of energy, unemployment, infrastructure, government expenditure, and investment do not have a statistically significant impact, although the direction of their coefficients indicates different relationship patterns. These findings confirm that, in the short term, the

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dynamics of economic growth in the SUMBAGUT region are more influenced by the correction mechanism toward long-term equilibrium than by direct fluctuations in economic variables.

Long-Run ARDL Estimation

The results of the long-term relationship estimation between the independent variables and economic growth using the ARDL panel model are presented in Table 5. Based on the long-term ARDL panel model estimation results in Table 5, the relationship between the independent variables and the dependent variable, economic growth, exhibits varying directions and levels of influence. These results provide an overview of the main factors influencing long-term economic growth in the North Sumatra region (SUMBAGUT).

Table 5 Long-Term Estimation Test Results for the SUMBAGUT Region

Variable	Coefficient	Std. Error	t-statistic	Prob.*
Energy	0.180524	0.042871	4.210845	0.0001
Unemployment	0.043240	0.011671	3.704859	0.0005
Infrastructure	0.097049	0.024037	4.037460	0.0002
Government Expenditure	0.132046	0.023252	5.678826	0.0000
Investment	-0.007998	0.001349	-5.928981	0.0000

*Note: * significance at the 5 percent level*
Source: Estimated Results, 2026.

Energy (ENG) has a coefficient of 0.180524 with a probability value of 0.0001, which is significant at the 5 percent confidence level. These results indicate that energy has a positive and significant impact on economic growth in the SUMBAGUT region in the long term. This means that an increase in energy use or availability can stimulate production activities, strengthen the industrial sector, and enhance regional economic efficiency. Sufficient energy becomes a strategic factor in supporting sustainable economic development in this region.

Unemployment (UN) shows a positive coefficient of 0.043240 with a probability value of 0.0005, which is significant at the 5 percent level. This result indicates a positive long-term relationship between the unemployment rate and economic growth, which can be interpreted paradoxically. This condition can occur if the increase in unemployment is accompanied by an increase in the participation of new labor forces, or if there is an economic restructuring process that creates new jobs with a time lag. In other words, economic growth may not yet be able to absorb all available labor in the short term, but in the long term, it can have a positive impact thru increased productivity.

Infrastructure (INFRA) has a positive coefficient of 0.097049 and a probability value of 0.0002, indicating statistical significance. These results indicate that infrastructure development has a positive and significant impact on long-term economic growth in the SUMBAGUT region. The improvement in the quality and quantity of infrastructure, such as roads, electricity, and logistics networks, can facilitate the distribution of goods and services, reduce production costs, and expand inter-regional connectivity, thereby supporting regional economic growth.

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Government expenditure (GE) has a positive coefficient of 0.132046 with a probability value of 0.0000, which is also significant at the 1 percent confidence level. This result indicates that an increase in government expenditure plays a positive and significant role in long-term economic growth. Government expenditure focused on infrastructure development, education, and public services can drive increased economic activity and provide a multiplier effect on productive sectors in the SUMBAGUT region.

On the contrary, investment has a negative coefficient of -0.007998 with a probability value of 0.0000, which is significant at the 5 percent confidence level. These results indicate that an increase in investment or capital formation actually has a negative impact on long-term economic growth. This phenomenon may be caused by low investment efficiency, delays in project implementation, or the dominance of investment in less productive sectors. This condition indicates that the quality of investment in the SUMBAGUT region needs to be improved to be more effective in driving economic output.

Overall, the long-term ARDL panel estimation results indicate that energy (ENG), infrastructure (INFRA), and government expenditure (GE) have a positive and significant impact on long-term economic growth in the SUMBAGUT region, while unemployment (UN) shows a positive relationship that needs further investigation, and investment has a significant negative impact. Thus, efforts to enhance long-term economic growth in the SUMBAGUT region need to focus on strengthening the energy sector, accelerating infrastructure development, and optimizing productive government expenditure, along with improving the quality of investments to make a tangible contribution to sustainable economic development.

The findings of this study reveal several results that are not entirely consistent with previous research, thereby emphasizing the importance of subregional analysis, such as in the SUMBAGUT region. While the positive effect of energy aligns with Ahmad et al. (2026) and Buhaerah (2016), the finding that unemployment has a positive and significant impact on economic growth contradicts Urbanski (2022), who reported a negative long-term effect, and differs from Sun and Husen (2025), who found no significant relationship in Indonesia. These discrepancies suggest that the labor market structure and sectoral dynamics in SUMBAGUT may differ substantially from those observed in other regions or countries.

Furthermore, the negative and significant impact of investment found in this study empirically supports the findings of Santoso et al. (2025) and Ridha and Parwanto (2020) yet theoretically challenges the neoclassical growth assumption that investment serves as a primary driver of economic expansion. Meanwhile, whereas previous studies such as Sari and Sari (2021) and Syaichoni et al. (2025) reported insignificant or suboptimal effects of infrastructure and government expenditure, this study demonstrates positive and significant long-term impacts in the SUMBAGUT region. These contrasting findings highlight the contribution of this research in providing more contextualized and comprehensive empirical evidence at the subregional level, particularly in SUMBAGUT.

CONCLUSION

Based on the Panel Autoregressive Distributed Lag (ARDL) analysis, this study finds evidence of a long-term relationship among energy, unemployment, infrastructure, government expenditure, investment, and economic growth in the SUMBAGUT region. The presence of this

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long-term relationship is indicated by a negative and statistically significant Error Correction Term (ECT), suggesting that any deviation from the long-run equilibrium will gradually adjust back toward equilibrium over time.

Energy has a positive and significant long-term influence on economic growth in the SUMBAGUT region. This finding indicates that increased energy availability and utilization play an important role in stimulating production activities and regional economic growth. However, in the short term, the effect of energy on economic growth is not statistically significant, suggesting that the impact of energy requires time to be fully realized.

Unemployment does not significantly impact short-term economic growth in the North Sumatra region. However, over the long term, unemployment has a significant impact on the region. This indicates that employment issues in North Sumatra are more closely linked to economic growth dynamics than in the Sumatra region as a whole.

In the short term, infrastructure does not show a significant impact on economic growth in the SUMBAGUT region. However, in the long term, infrastructure demonstrates a statistically significant effect on economic growth. These findings suggest that infrastructure development requires time to generate measurable economic impacts, with its effectiveness becoming more apparent in the long run through improved connectivity, distribution efficiency, and regional productivity.

Government spending does not significantly impact short-term economic growth in the West Sumatra region. However, in the long term, government spending significantly impacts economic growth. This indicates that the effectiveness of government spending is more evident in the long term, as development programs and budget allocations begin to impact economic activity and increase regional productivity.

Meanwhile, investment has a negative and significant long-term impact on economic growth in SUMBAGUT. This result indicates that the investments made have not been fully efficient in driving economic growth, possibly due to less productive or misallocated investments. In the short term, investment has not shown a significant impact on economic growth in SUMBAGUT.

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