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Analysis Of Infrastructure, Investment, And Human Capital On Economic Growth In Sumatra Provinces, 2016–2024

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ABSTRACT

Regional economic growth is an important indicator in assessing the success of regional development. However, inequality in growth between provinces remains a major challenge in Sumatra Island. This research aims to analyze the influence of basic infrastructure, domestic investment, and human capital on economic growth in ten provinces in Sumatra Island for the 2016–2024 period. The basic infrastructure variable is proxied by stable road conditions, access to proper sanitation, and access to proper clean water, while human capital is measured using the Gross Enrollment Ratio for Senior High School (GER SHS). Economic growth is measured using Gross Regional Domestic Product (GRDP) per capita. The analysis method used is panel data regression with a Fixed Effect Model approach, which was chosen based on the results of the Chow test and Hausman test. Estimation results show that access to clean water and Domestic Investment (DI) have a positive and significant effect on economic growth in provinces in Sumatra Island. Meanwhile, stable road conditions show a negative influence at a certain level of significance, while sanitation access and GER SHS do not have a statistically significant effect. These findings indicate that the quality of basic infrastructure and domestic investment have a strategic role in encouraging regional economic growth, although the effectiveness of each infrastructure component differs between provinces. This research provides important policy implications for local governments in determining infrastructure development priorities and investment increase strategies to support more inclusive economic growth in Sumatra Island

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INTRODUCTION

Regional economic growth is the primary indicator of regional development success as it reflects increased production capacity, public welfare, and efficient utilization of economic resources. In the context of economic development, sustainable growth is not only measured by increased output but also by a region's ability to create development equity and reduce inter-regional disparities (Todaro & Smith, 2012). However, experience in various developing countries shows that economic growth is often distributed unevenly, thus giving rise to development gaps between regions.

Sumatra Island is one of the strategic regions in the Indonesian economy, serving as a primary economic corridor and a center for leading commodity production. Despite possessing potential natural resources and a strategic geographical position, the rate of economic growth between provinces on Sumatra Island still shows considerable variation. Such differences indicate inequality in development quality, particularly regarding the availability of basic infrastructure, investment, and human resource quality. The World Bank emphasizes that differences in access to key production factors are a major cause of economic performance disparities between regions in developing countries (World Bank, 2023).

Basic infrastructure is a crucial determinant in driving regional economic growth. Road infrastructure, clean water access, and proper sanitation function as prerequisites for smooth economic activity, increased productivity, and the efficiency of goods and services distribution. Adequate infrastructure development is capable of lowering logistics costs, expanding inter-regional connectivity, and creating a more conducive business climate (Calderon & Serven, 2010). Empirical studies in Indonesia show that basic infrastructure, such as roads and basic residential services, significantly influences the increase in Gross Regional Domestic Product (GRDP) and regional economic growth (Maryaningsih et al., 2014; Nugraha et al., 2020). Nevertheless, the effectiveness of each infrastructure component may differ across regions, depending on the economic and geographical characteristics of the area.

Besides infrastructure, domestic investment also plays a strategic role in the process of economic growth. The Harrod-Domar growth theory explains that investment functions to increase capital stock which ultimately expands production capacity and drives long-term economic growth (Ma'ruf & Wihastuti, 2008). Domestic Investment (DI) possesses advantages due to its strong linkage with local economic structures as well as its contribution to job creation and public income enhancement (Makmun & Yasin, 2003; Sukirno, 2010). A number of studies indicate that increased domestic investment has a positive effect on regional economic growth, although the magnitude of this influence is

highly dependent on the quality of infrastructure and the regional economic environment (Yuliana et al., 2019).

Another factor that determines economic growth is human capital quality. Neoclassical and endogenous growth theories emphasize that education plays an important role in increasing labor productivity and the ability to adapt to technological changes (Barro & Sala-i-Martin, 2004). In this context, the Gross Enrollment Ratio for Senior High School (GER SHS) can be used as an indicator of school-age population involvement in secondary education, reflecting the potential quality of human resources in a region. Research by (Utama & Soesanti, 2019) shows that secondary education participation has a long-term linkage with economic growth in Indonesia. However, some studies also find that the influence of education on economic growth is not always significant in the short term, especially if the economic structure is unable to optimally absorb educated labor.

A number of previous empirical studies have examined the relationship between infrastructure, investment, and economic growth. Rajaguguk (2020) and Novitasari et al. (2020) found that road infrastructure, sanitation, and clean water access have a positive influence on regional economic performance. However, most of these studies are still sectoral or focused on specific regions, particularly Java. Studies integrating various basic infrastructure components alongside Domestic Investment (DI) and human capital on a provincial scale on Sumatra Island are still relatively limited. Yet, the heterogeneous characteristics of Sumatra Island, both in terms of geography and economic structure, demand a more comprehensive and contextual analysis approach.

Based on this background, this study aims to analyze the influence of basic infrastructure, Domestic Investment (DI), and human capital on economic growth in ten provinces on Sumatra Island for the 2016–2024 period. Basic infrastructure is proxied through stable road conditions, proper sanitation access, and proper clean water access, while human capital is measured using the GER SHS. Economic growth is measured using Gross Regional Domestic Product (GRDP) per capita. By utilizing a panel data regression approach, this study is expected to provide stronger empirical evidence regarding the determinants of regional economic growth and serve as a policy development reference that is more effective and oriented toward equity in Sumatra Island.

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Figure 1. Research Location Map of Provinces on Sumatra Island

METHOD

This study utilizes a quantitative approach with the panel data regression analysis method. A quantitative approach was chosen because it allows for testing causal relationships between variables based on numerical data and measurable statistical analysis (Widarjono, 2018). Panel data is a combination of time series data and cross-sectional data, thereby enabling the capture of variable change dynamics across regions and time simultaneously. The use of panel data provides several advantages compared to purely cross-sectional or time-series data, including increasing the number of observations, enlarging the degrees of freedom, and reducing potential bias due to the omission of unobserved variables (omitted variable bias) (Widarjono, 2005).

Data and Data Sources

This research employs secondary data in the form of annual panel data covering ten provinces in Sumatra Island during the 2016–2024 period. The selection of the research period is based on relatively consistent data availability and reflects the dynamics of infrastructure development and investment in the last decade, including the periods before and after the COVID-19 pandemic. The research data were obtained from several official sources such as Badan Pusat Statistik, Kementerian Pekerjaan Umum, and Badan Koordinasi Penanaman Modal (BKPM) (Badan Koordinasi Penanaman Modal, 2026). The use of data from official government institutions aims to ensure the validity and reliability of the data used in the empirical analysis.

Research Variables and Operational Definitions

The dependent variable in this study is regional economic growth proxied by the Gross Regional Domestic Product (GRDP) per capita at constant market prices. GRDP per capita

is used as an indicator of regional economic performance as it reflects the average output level produced per resident and is frequently utilized in regional economic growth analysis (Badan Pusat Statistik, 2025).

The independent variables consist of basic infrastructure, domestic investment, and human capital. Basic infrastructure is proxied through stable road conditions (kilometers), the percentage of households with access to proper sanitation, and the percentage of households with access to proper clean water. The selection of these variables is based on literature stating that basic infrastructure plays an important role in enhancing regional economic productivity and efficiency (Calderon & Serven, 2010; Nugraha et al., 2020).

Domestic investment is measured using the realization value of Domestic Investment (DI). DI is viewed as a key factor in increasing production capacity, creating employment, and strengthening local economic activities ((Makmun & Yasin, 2003; Sukirno, 2010). Meanwhile, human capital is proxied through the Gross Enrollment Ratio for Senior High School (GER SHS), which reflects the involvement level of the school-age population in secondary education and the potential quality of human resources in a region (Utama & Soesanti, 2019).

Table 1. Descriptive Statistics of Research Variables

Variabel	Satuan	Mean	Minimum	Maksimum	Standar Deviasi
GRDP (Y)	Rp	2.36E+11	4.01E+10	6.33E+11	1.67E+11
Stable Road Conditions (ROAD)	km	74,83	43,86	96,71	11,50
Access to Proper Sanitation (SAN)	%	76,46	42,71	94,16	11,44
Access to Proper Clean Water (WTR)	%	77,60	37,35	94,71	12,19
Domestic Investement (DI)	Rupiah	1,02E+13	2,97E+11	6,11E+13	1,07E+13
Gross Enrollment Ratio for Senior High School (GER SHS)	%	188,92	77,40	9.200,00	960,54

Source: Processed Data, 2026

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Analysis Model

To analyze the influence of basic infrastructure, domestic investment, and human capital on economic growth, this study utilizes the following panel data regression model:

$$GRDP_{it} = \alpha + \beta_1 ROAD_{it} + \beta_2 SAN_{it} + \beta_3 WTR_{it} + \beta_4 DI_{it} + \beta_5 GERSHS_{it} + \varepsilon_{it}$$

Where:

- $GRDP_{it}$ is the Gross Regional Domestic Product per capita of province i in year t
- α is the constant
- $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ are the regression coefficients of each independent variable
- $ROAD_{it}$ is the length of roads in stable condition
- SAN_{it} is the percentage of access to proper sanitation
- WTR_{it} is the percentage of access to proper clean water
- DI_{it} is the realization value of Domestic Investment
- $GERSHS_{it}$ is the Gross Enrollment Ratio for Senior High School
- ε_{it} is the error term
- $i = 1,2,3, \ldots 10$ indicates the province
- $t = 2016, \ldots, 2024$ indicates the time period

In panel data regression, there are three commonly used estimation approaches: the Common Effect Model (CEM), the Fixed Effect Model (FEM), and the Random Effect Model (REM). CEM assumes that there are no differences in characteristics between individuals or time, while FEM accommodates differences in characteristics between individuals through intercept differences. Meanwhile, REM assumes that individual differences are random and become part of the error component (Widarjono, 2018).

Estimation Model Selection

The selection of the best model is carried out through two testing stages. First, the Chow Test is used to determine the more appropriate model between CEM and FEM. If the test probability value is smaller than the 5 percent significance level, then FEM is selected as the more appropriate model. Second, if FEM is selected, the Hausman Test is performed to determine whether FEM or REM is more appropriate for use in the analysis. The Hausman Test is based on a comparison of estimator consistency with the Chi-square probability value criterion (Widarjono, 2018).

Classical Assumption Test and Hypothesis Testing

To ensure the validity of the estimation results, this research conducts classical assumption tests, including tests for normality, multicollinearity, heteroscedasticity, and autocorrelation. These tests aim to ensure that the regression model meets the basic assumptions of the estimation method so that the estimation results are unbiased and efficient (Ghozali, 2017). Furthermore, hypothesis testing is conducted through the t-test to determine the partial influence of each independent variable on the dependent variable, and

the F-test to determine the simultaneous influence of the independent variables. The significance levels used in this study are 5 percent and 10 percent, as commonly used in empirical economic research (Ghozali, 2005).

RESULTS AND DISCUSSION

Panel Data Regression Model Selection

Before conducting the panel data regression estimation, the best model selection was performed to ensure consistent and efficient estimation results. Model selection was carried out through the Chow Test and the Hausman Test. The results of the Chow Test indicate that the probability value is smaller than the 5 percent significance level, thus the Common Effect Model is rejected and the Fixed Effect Model (FEM) is more appropriate for use.

Furthermore, the Hausman Test results also show a Chi-square probability value smaller than 5 percent, so the Random Effect Model is rejected and FEM is established as the final estimation model. The selection of FEM indicates that there are specific characteristics varying across provinces on Sumatra Island that influence economic growth. Thus, the use of FEM is considered appropriate as it is capable of accommodating inter-provincial heterogeneity that cannot be directly observed (Widarjono, 2018).

Table 2. Results of Panel Data Regression Model Selection Tests Panel

A. Chow Test Results

Redundant Fixed Effects Tests
Equation: Untitled
Test cross-section fixed effects

Effects Test	Statistic	d.f.	Prob.
Cross-section F	466.599524	(9,75)	0.0000
Cross-section Chi-square	363.861891	9	0.0000

Test	Statistic	Degrees of Freedom	Probability	Decision
Chow Test (Cross-section F)	413.7686	(9; 75)	0.0000	Fixed Effect Model is more appropriate

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Panel B. Hausman Test Results

Correlated Random Effects - Hausman Test
Equation: Untitled
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	69.788432	5	0.0000

Test	**Chi-Square Statistic**	**Degrees of Freedom**	**Probability**	**Decision**
Hausman Test	13.8644	5	0.0165	Fixed Effect Model is more appropriate

The results of the panel data regression model selection tests are presented in Table 2. Based on the Chow Test results, the probability value being smaller than the 5 percent significance level indicates that the Common Effect Model is rejected and the Fixed Effect Model is more appropriate for use. Subsequently, the Hausman Test results also show a Chi-square probability value smaller than 5 percent, thus the Random Effect Model is rejected and the Fixed Effect Model is established as the final estimation model.

Panel Data Regression Estimation Results

Table 3. Panel Data Regression Estimation Results: Fixed Effect Model

Independent Variable	Coefficient	t-Statistik	Probability
Constant	155.569,9	1,5310	0,1300
Road in Stable Conditions (ROAD)	−425,8151	−1,8577	0,0401*
Access to Proper Sanitation (SAN)	15,5817	0,0453	0,9766
Access to Proper Clean Water (WTR)	1.202,6880	3,3630	0,0012***
Gross Enrollment Ratio for Senior High School (GER SHS)	0,7985	1,0324	0,3052
Domestic Investement (DI)	1,7112	7,9164	0,0000***

Description	Value
R-squared	0.9928
Adjusted R-squared	0.9927
F-statistic	738.7296
Prob(F-statistic)	0.0000
Durbin-Watson	1.9929

Note:

*** significant at α = 1 %;

** significant at α = 5%;

* significant at α = 10%.

Source: Panel data regression estimation results using EViews (processed by the author).

The results of the panel data regression estimation using the Fixed Effect Model approach are presented in Table 3. Simultaneously, all independent variables have a significant effect on GRDP per capita, as indicated by the F-statistic probability value being smaller than the 5 percent significance level. Partially, the variables of access to clean water and Domestic Investment (DI) have a positive and significant effect on economic growth. Meanwhile, stable road conditions show a negative influence at a 10 percent significance level, whereas proper sanitation access and the Gross Enrollment Ratio for Senior High School (GER SHS) do not have a statistically significant effect.

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Development of Average GRDP per Capita of Provinces in Sumatra Island Year 2016–2024

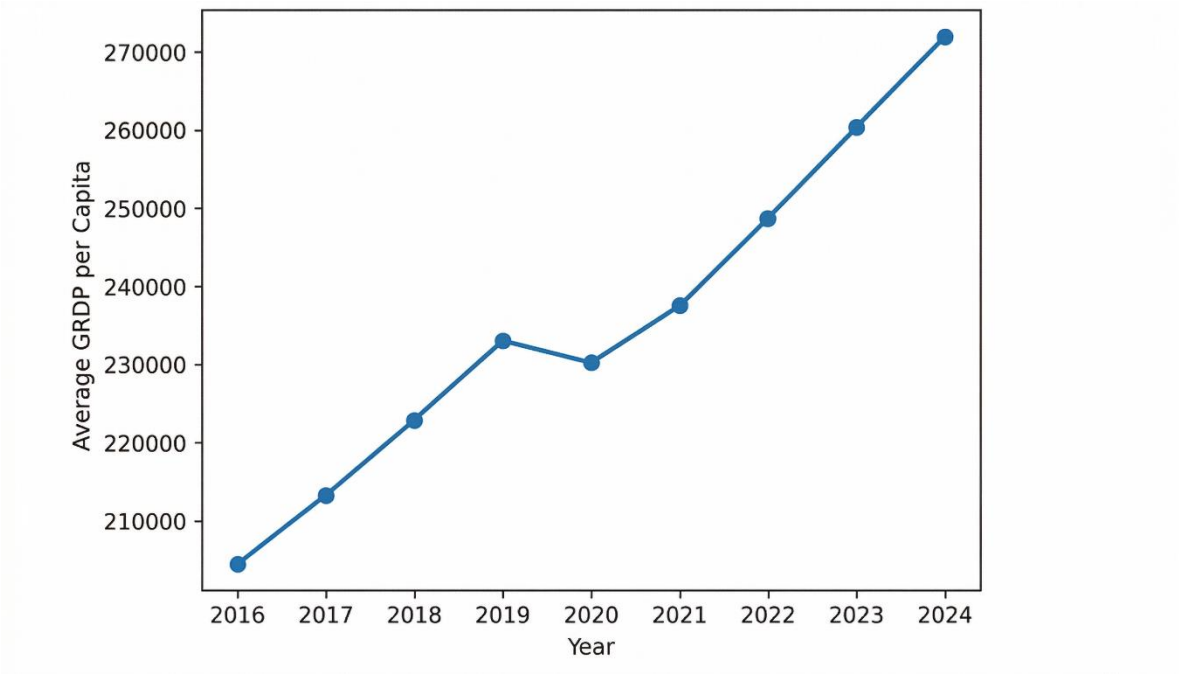

Figure 2. Development of Average GRDP per Capita of Provinces in Sumatra Island Year 2016–2024

Description:

This figure shows the development trend of the average Gross Regional Domestic Product (GRDP) per capita of provinces on Sumatra Island during the 2016–2024 period. A slowdown in growth is observed in 2020 related to the COVID-19 pandemic, followed by economic recovery in the subsequent period.

Source: Central Bureau of Statistics (data processed by the author).

Partially, the estimation results show that clean water access and Domestic Investment (DI) have a positive and significant effect on GRDP per capita. These findings indicate that increasing clean water access and increasing domestic investment directly drive economic activity and community productivity. Meanwhile, the stable road conditions variable shows a negative influence at a certain significance level, whereas proper sanitation access and the Gross Enrollment Ratio for Senior High School (GER SHS) do not show a statistically significant effect on economic growth.

The high coefficient of determination (R^2) value indicates that the variation in GRDP per capita of provinces on Sumatra Island can be largely explained by the variables used in the

model. This signifies that basic infrastructure, domestic investment, and human capital are important determinants in explaining the dynamics of regional economic growth.

Influence of Road Infrastructure on Economic Growth

Estimation results show that stable road conditions have a negative influence on economic growth at a certain significance level. This finding differs from most literature stating that road infrastructure has a positive effect on economic growth (Calderon & Serven, 2010; Maryaningsih et al., 2014). However, this result can be explained by several contextual factors.

First, road construction on Sumatra Island has not been fully integrated with productive economic activity centers. An increase in road length or quality that is not accompanied by the development of the local economic sector has the potential to cause a *leakage effect*, where economic benefits are instead enjoyed by other regions that are more structurally prepared. Second, in several provinces, road construction is more of a maintenance nature rather than an expansion of new economic capacity, so its impact on short-term economic growth becomes limited. A similar phenomenon has also been found in several empirical studies showing that the impact of road infrastructure on growth can be negative or insignificant in certain periods ((Syadullah & Setyawan, 2021).

Influence of Proper Sanitation Access on Economic Growth

The proper sanitation access variable does not show a significant influence on economic growth. This finding indicates that although sanitation is an important component of human development, its impact on economic growth tends to be indirect and long-term. Good sanitation contributes to improved public health, which ultimately increases labor productivity; however, such effects are not always directly reflected in GRDP per capita increases in the short term (Novitasari et al., 2020; Rajagukguk, 2021). This result also indicates that improving sanitation needs to be synergized with other factors, such as employment opportunities and the quality of other supporting infrastructure, to provide a more tangible economic impact.

Influence of Clean Water Access on Economic Growth

Clean water access shows a positive and significant influence on the economic growth of provinces on Sumatra Island. This finding is in line with research (Nugraha et al., 2020; Siswantoro, 2024), stating that clean water availability contributes to increased health, productivity, and community welfare. Adequate clean water access reduces disease risk, suppresses health costs, and increases time and labor efficiency, thereby directly impacting increased economic output. In the context of Sumatra Island, clean water access becomes a crucial factor given the remaining disparities in basic services between provinces and sub-regions. Therefore, this finding confirms that clean water infrastructure development has a strategic role in driving more inclusive regional economic growth.

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Influence of Domestic Investment (DI) on Economic Growth

Research results show that DI has a positive and significant effect on economic growth. This finding is consistent with the Harrod-Domar growth theory, which emphasizes the role of investment in increasing production capacity and driving economic growth (Ma'ruf & Wihastuti, 2008). Domestic investment also strengthens local economic linkages through job creation and community income increases (Makmun & Yasin, 2003; Sukirno, 2010). This result is in line with research, which found that investment has a significant influence on regional economic growth (Yuliana et al., 2019). Thus, improving the domestic investment climate on Sumatra Island is a vital key in accelerating regional economic growth.

Influence of Gross Enrollment Ratio for Senior High School on Economic Growth

The GER SHS variable does not show a significant influence on economic growth. This finding indicates that the increase in secondary education participation has not been directly translated into increased economic output. This could be caused by a *time lag* between educational improvement and its impact on economic productivity, as well as limitations in absorbing educated labor in productive sectors (Barro & Sala-i-Martin, 2004). This result is in line with the findings which state that the influence of education on economic growth tends to be stronger in the long term than in the short term (Utama & Soesanti, 2019). Therefore, education improvement policies need to be accompanied by job creation and economic structure transformation so that the impact on growth becomes more optimal.

CONCLUSION

This study aims to analyze the influence of basic infrastructure, domestic investment, and human capital on economic growth in ten provinces on Sumatra Island during the 2016–2024 period using a panel data regression approach. The estimation results show that simultaneously, the variables of basic infrastructure, Domestic Investment (DI), and human capital have a significant influence on regional economic growth as measured through Gross Regional Domestic Product (GRDP) per capita.

Partially, the research results show that access to clean water and DI have a positive and significant effect on the economic growth of provinces on Sumatra Island. These findings confirm that clean water infrastructure development plays a strategic role in increasing public productivity, suppressing health costs, and strengthening local economic activities. Therefore, local governments need to place the provision of clean water access as one of the main priorities in basic infrastructure development planning, especially in provinces that still experience basic service limitations.

The research results also show that DI is an important factor in driving regional economic growth. Domestic investment contributes directly to increasing production capacity, job creation, and strengthening regional economic structures. The policy implication of this finding is the need for local governments to strengthen a conducive investment climate through simplifying permits, increasing regulatory certainty, and providing adequate supporting infrastructure so that domestic investment can grow sustainably on Sumatra Island.

Meanwhile, stable road conditions show a negative influence at a certain level of significance on economic growth. This finding indicates that road infrastructure development that is not integrated with productive economic activity centers has the potential to produce limited economic benefits in the short term. Therefore, road construction needs to be directed toward a more integrated approach based on regional needs, so that it is capable of encouraging effective economic connectivity and reducing the potential for inequality between provinces.

The variables of proper sanitation access and the Gross Enrollment Ratio for Senior High School (GER SHS) do not show a significant influence on economic growth. These findings indicate that the impact of sanitation and secondary education on economic growth tends to be indirect and requires time to provide a real effect. Therefore, policies to improve the quality of sanitation and education need to be synergized with job creation policies and the strengthening of productive sectors so that their contribution to economic growth can be more optimal.

Overall, the results of this research emphasize the importance of an integrated development approach between the provision of basic infrastructure, the strengthening of domestic investment, and the improvement of human resource quality. Local governments on Sumatra Island are expected to utilize these empirical findings as a basis for formulating development policies that are more targeted, equity-oriented, and capable of driving inclusive and sustainable regional economic growth.

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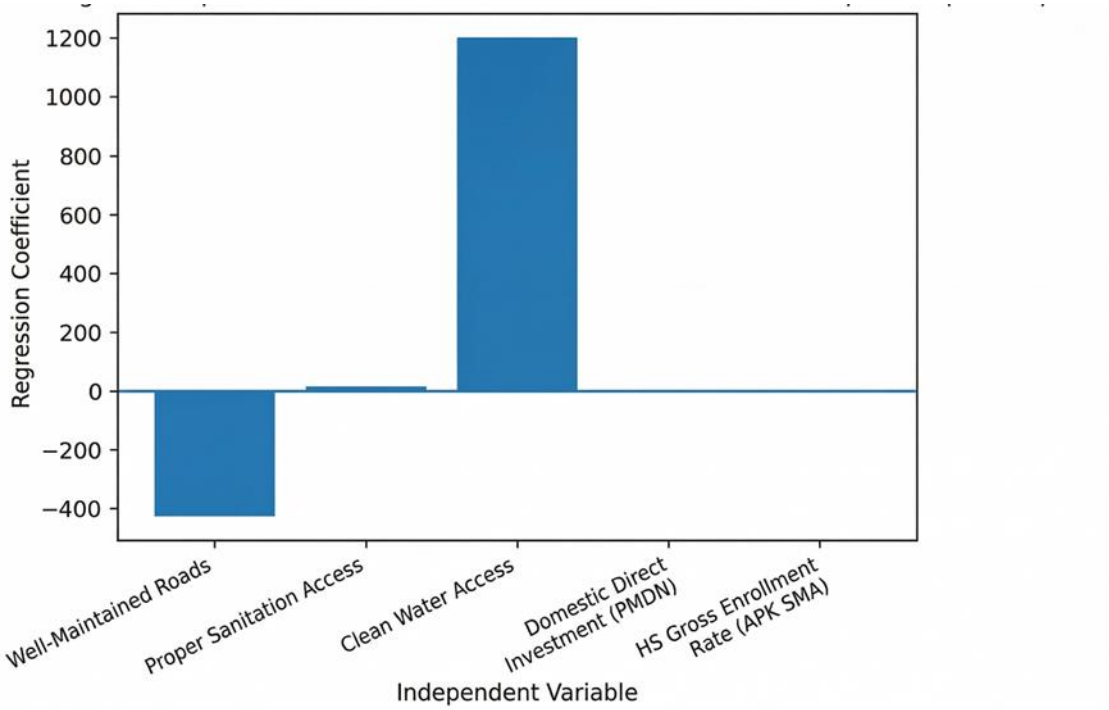

Figure 3. Comparison of the Impact of Infrastructure and Investment Variables on GRDP per Capita

Source: Panel data regression estimation results (processed by the author).

The figure above shows a comparison of the regression coefficients for the variables of basic infrastructure, Domestic Investment (DI), and human capital toward Gross Regional Domestic Product (GRDP) per capita based on the Fixed Effect Model estimation results. A positive coefficient indicates a direct relationship with economic growth, while a negative coefficient indicates an inverse relationship.

Based on Figure 3, differences in the direction and magnitude of the influence of each independent variable on GRDP per capita are observed. The clean water access variable shows the largest positive coefficient, indicating that increasing clean water access provides the strongest impact on regional economic growth. This confirms the strategic role of clean water infrastructure in increasing public productivity and the efficiency of economic activities.

Domestic Investment (DI) also shows a positive and significant coefficient, reflecting that increased domestic investment consistently drives production capacity and economic activity in the provinces of Sumatra Island. Although the coefficient value of DI is relatively smaller compared to clean water infrastructure, its significance indicates that investment is an important factor in regional economic growth.

Conversely, the stable road condition variable shows a negative coefficient, indicating that the improvement of stable roads has not fully provided a positive impact on economic growth. This finding suggests a mismatch between road development and the

needs of productive economic sectors, such that the economic benefits generated are not yet optimal in the short term.

The proper sanitation access and Gross Enrollment Ratio for Senior High School (GER SHS) variables show positive but statistically insignificant coefficients. This indicates that the impact of sanitation and secondary education on economic growth tends to be indirect and requires a longer time to provide a tangible effect on the increase of GRDP per capita.

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