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SOCIAL AND ENVIRONMENTAL DYNAMICS IN ECONOMIC RESILIENCE: A REVIEW OF THE INFLUENCE ON GRDP

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ABSTRACT

This study analyzes the influence of social and environmental dynamics on economic resilience, which is measured through Gross Regional Domestic Product (GRDP) on the island of Sumatra during the period 2011 to 2022. Considering the increasing uncertainty in the global economy due to climate change, this research aims to analyze how factors such as Poverty level, unemployment rate, Human Development Index (HDI), air quality index, water quality index and environmental quality index affect GRDP. Using a quantitative approach, secondary data from ten provinces in Sumatra during the period 2011 to 2022 was analyzed using the panel data regression method. The findings show that poverty has a significant negative effect on GRDP, while HDI has a positive effect on GRDP. In addition, air and water quality indices have a negative impact on GRDP, highlighting the need for effective environmental management strategies. This research underscores the important relationship between environmental conditions and economic performance, showing that sustainable development strategies are critical to increasing economic resilience in vulnerable regions such as Sumatra.

Keywords : *Social and Environmental Dynamics[1], Economic Resilience[2], GRDP[3], Poverty[4], Environmental Quality[5]*

ABSTRAK

Penelitian ini menganalisis pengaruh dinamika sosial dan lingkungan terhadap ketahanan ekonomi yang diukur melalui Produk Domestik Regional Bruto (PDRB) di Pulau Sumatera selama periode 2011 hingga 2022. Mengingat meningkatnya ketidakpastian dalam perekonomian global akibat perubahan iklim, penelitian ini bertujuan untuk menganalisis bagaimana faktor-faktor seperti tingkat kemiskinan, tingkat pengangguran, Indeks Pembangunan Manusia (IPM), indeks kualitas udara, indeks kualitas air, dan indeks kualitas lingkungan mempengaruhi PDRB. Dengan menggunakan pendekatan kuantitatif, data sekunder dari sepuluh provinsi di Sumatera selama periode 2011 hingga 2022 dianalisis dengan menggunakan metode regresi data panel. Hasil penelitian menunjukkan bahwa kemiskinan berpengaruh negatif signifikan terhadap PDRB, sedangkan IPM berpengaruh positif terhadap PDRB. Selain itu, indeks kualitas udara dan air memiliki dampak negatif terhadap PDRB, menyoroti perlunya strategi pengelolaan lingkungan yang efektif. Penelitian ini menggarisbawahi hubungan penting antara kondisi lingkungan dan kinerja ekonomi, yang menunjukkan bahwa strategi pembangunan berkelanjutan sangat penting untuk meningkatkan ketahanan ekonomi di daerah yang rentan seperti Sumatera.

Kata kunci : Dinamika Sosial dan Lingkungan[1], Ketahanan Ekonomi[2], PDRB[3], Kemiskinan[4], Kualitas Lingkungan[5]

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INTRODUCTION

Economic resilience is an important issue globally, especially for Indonesia, where external shocks such as the COVID-19 pandemic, geopolitical instability, and climate change have a significant impact on economic stability. In this context, ensuring economic resilience requires not only sectoral productivity but also social stability and environmental sustainability. Economic development that only refers to profit without paying attention and considering the sustainability of nature and the environment will not only bring negative impacts to nature but will also be felt by humans (Nikensari et al., 2019). Sumatra, as one of Indonesia's major economic regions, contributes significantly to national GDP, but faces challenges related to environmental degradation and social inequality. Therefore, understanding the linkages between social, environmental and economic factors is important to formulate policies that can improve economic resilience in this region.

This study aims to explore and analyze the impact of environmental quality on regional economic performance in Sumatra, focusing on key factors such as air pollution, water quality, and overall environmental quality index. Unlike previous studies that focused solely on economic indicators, this study integrates environmental dynamics as a determinant of GRDP, thus providing new insights into the balance between economic growth and sustainability. Sumatra accounts for about 21.70% of Indonesia's national GDP, with a population of more than 58 million. The region's economy relies heavily on agriculture (22.27%), industry (20.24%) and mining (15.95%), yet structural issues such as inadequate infrastructure and human resource development hinder its economic potential. Therefore, understanding the interactions between social and environmental factors is crucial for crafting more effective and sustainable development policies.

This research builds on the Endogenous Growth Theory, which emphasizes human capital and innovation as key drivers of economic resilience. The study also applies the Environmental Kuznets Curve (EKC) Hypothesis, which states that economic growth initially causes environmental degradation, but then leads to improved environmental quality as people begin to prioritize sustainability. Understanding how these theories materialize in the context of Sumatra can provide a better perspective on economic-environment interactions in developing regions, aiding the formulation of more effective

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policies to improve the region's economic resilience. Social dynamics include aspects such as the poverty rate, unemployment rate and HDI, each of which contributes differently to the region's economic resilience. The poverty rate, describing how large a share of the population still has difficulty meeting basic needs, can hinder economic growth and reduce the resilience of a society to external economic shocks. Poverty reduction can increase household production and boost economic growth in a region (Munir & Nurohman, 2021). High poverty will reduce people's purchasing power and suppress demand in the domestic economy. Ultimately, high poverty will create a negative ecosystem that will hinder economic growth in a region (Putra et al., n.d.).

A high unemployment rate also indicates weak labor market absorption, which reduces the contribution of labor in production activities and limits economic growth. Hannyfah et al. suggested that high unemployment in various provinces in Indonesia has a negative correlation with GRDP growth, because high unemployment reduces community productivity and suppresses government spending on social safety nets (Hannyfah et al., 2023). In line with research by Abubakar et al., that the partial test results show that the unemployment variable has a negative and insignificant effect on GRDP (Abubakar et al., 2022). Therefore, reducing unemployment can increase economic resilience through increased productivity and better labor capacity.

Money In addition, the Human Development Index (HDI), which includes dimensions of health, education and living standards, is one of the most influential indicators of economic resilience. An increase in the Human Development Index (HDI) reflects improvements in people's quality of life and productivity, which in turn will increase the region's economic capacity in the long run. Research by Budihardjo et al. shows that a high HDI has a positive impact on GRDP, as a healthy, educated, and well-off society is able to contribute more to economic growth (Budihardjo et al., 2020).

In addition to social dynamics, environmental dynamics such as air quality, water quality, and environmental quality play a major role in economic resilience. Environmental degradation, such as air and water pollution, has a negative impact on public health, labor productivity, and the sustainability of key sectors that depend on natural resources. According to Yani et al., increased air pollution in several provinces in Sumatra has

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resulted in increased health costs and decreased labor productivity, which in turn hampers the region's economic growth (Yani et al., 2023). Poor water quality also impacts sectors that depend on clean water supply, such as agriculture and fisheries. Research by Damayanti revealed that water pollution increases agricultural production costs, which in turn decreases the competitiveness of the regional economy (Damayanti, 2016).

The Environmental Quality Index (EQI) is a key indicator that describes the overall condition of the ecosystem. Declining environmental quality can affect the region's attractiveness for investment, reduce productivity in the industrial sector, and increase pollution control costs. The environmental quality index will affect national income, where an increase or decrease in the value of this index can have an impact on economic growth and people's welfare (Pratama, Citra, 2019). Research by Ramadhan shows that a decline in environmental quality has a significant impact on economic productivity, as it reduces regional competitiveness and makes it difficult to create new jobs (Ramadhan, 2023). Conversely, a healthy environment can support a strong economy through high productivity and good public health.

This study focuses on the island of Sumatra over the period 2011-2022, which is a region with a high dependence on sectors that are sensitive to changes in the environment and social dynamics. By looking at how the poverty rate, unemployment rate, HDI, and air, water and environmental quality indices affect GRDP, this study aims to provide a deeper understanding of the influence of social and environmental variables on economic resilience in Sumatra Island. The findings of this study are expected to provide input for the government and policy makers in designing economic development strategies that are not only growth-oriented, but also consider social and environmental sustainability as part of long-term economic resilience.

LITERATURE REVIEW

Endogenous growth theory is an economic approach that emphasizes that economic growth comes from factors internal to the economy, mainly human capital accumulation and innovation, instead of relying solely on external factors such as technological progress which are considered as exogenous variables. This theory was introduced by Paul Romer and Robert Lucas in the late 1980s as a critique of the neoclassical growth model, which

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views technological progress as a factor that cannot be influenced by economic policy. In the endogenous growth model, economic output (Y) is generated through a production function involving physical capital (K), labor (L), and human capital (H), with the basic equation Y = AK, where A reflects total factor productivity.

The Environmental Kuznets Curve (EKC) theory is a hypothesis that explains the relationship between economic growth and environmental quality, usually depicted as an "inverted U" curve. This EKC theory hypothesizes that in the early stages of growth, biodiversity tends to suffer and in the later stages will decline (Finanda & Gunarto, 2021). The EKC approach suggests that in the early stages of economic growth, environmental quality tends to deteriorate due to high exploitation of natural resources and intensive industrial activities. However, after reaching a turning point, an increase in per capita income can increase environmental awareness, encourage people and governments to invest in environmentally friendly technologies and implement more environmentally supportive policies (Pettinger, 2019). Thus, environmental quality can improve along with economic growth.

Economic resilience can be measured by looking at GRDP as the main indicator. GRDP reflects the economic capacity of a region to produce goods and services, and serves as an indicator of the region's economic resilience to internal and external disturbances, including the impacts of climate change. As one of the main variables in measuring economic performance, GRDP is influenced by various factors, both social and environmental, which interact with each other in a complex manner (Barika et al., 2024).

Poverty is one of the indicators that significantly affects the economic resilience of a region. Countries with lower poverty rates tend to have more stable GRDP and more sustainable economic growth (Roslyakova & Okrepilov, 2023). Based on research by Hannyfah et al., high poverty rates have a significant negative impact on GRDP in 34 provinces in Indonesia during the 2019-2021 period (Hannyfah et al., 2023). Meanwhile, according to Putra's research, poverty and the Human Development Index have a significant influence on GRDP (Putra et al., n.d.).

The unemployment rate has a major influence on GRDP and economic resilience, especially in the face of uncertainty caused by environmental changes. Research by

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Hannyfah et al. shows that “the greater the unemployment rate, the lower the GRDP of 34 provinces in Indonesia,” which indicates that an increase in unemployment has a negative impact on the economic growth of a region (Hannyfah et al., 2023). This result is in line with the findings of Rio Laksamana, who also found that GRDP has a negative and significant effect on unemployment in West Kalimantan, where an increase in GRDP contributes to a decrease in the unemployment rate (Laksamana, 2016). In addition, research by Geli, Harsono, and Widiawati revealed that GRDP has a positive effect on the unemployment rate in East Flores Regency, indicating that despite an increase in GRDP, this is not always followed by a decrease in unemployment, especially if economic growth is uneven (Geli et al., 2021).

The relationship between the Human Development Index (HDI) and Gross Regional Domestic Product (GRDP) is a central issue in economic development studies, where an increase in HDI is expected to contribute to GRDP growth. Research by Budihardjo, Arianti, and Mas'ud showed that “GRDP has a positive and significant effect on the Human Development Index,” with the results of the analysis showing that every 1% increase in GRDP can increase HDI by 0.39% (Budihardjo et al., 2020). This suggests that good economic growth can improve people's quality of life through increased access to education, health, and infrastructure. On the other hand, research by Sari and Setyowati found that “HDI has a positive effect on GRDP in Bali Island in 2010-2020,” which confirms that improving people's quality of life can contribute to regional economic growth (Sari & Setyowati, 2023).

The Environmental Quality Index (EQI), which includes the Air Quality Index (AQI) and Water Quality Index (WQI), has a close relationship with Gross Regional Domestic Product (GRDP) because environmental quality can affect economic productivity. Research shows that economic growth often contributes to a decline in environmental quality. In a study conducted by Yani et al., it was found that “economic growth has a significant negative effect on environmental quality” and “population density has a significant positive effect” on such quality. This suggests that increased economic activity, without proper management, can lead to adverse pollution of air and water quality, which in turn can affect public health and productivity (Yani et al., 2023).

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RESEARCH METHOD

This study uses quantitative methods with data covering economic and environmental indicators such as Gross Regional Domestic Product (GRDP), poverty rate, unemployment rate, Human Development Index (HDI), Air Quality Index (AQI), Water Quality Index (WQI), and Environmental Quality Index (EQI). Secondary data were obtained from the Central Bureau of Statistics and publications of the Ministry of Environment and Forestry, covering ten provinces in Sumatra Island between 2011 and 2022.

This study adopts a panel data design that combines cross-sectional and time series data for comprehensive analysis (Greene, 2012). The analysis was conducted using a panel data regression model with the analytical tool used was EViews 12 to evaluate the effect of Poverty, Unemployment Rate, Human Development Index, Air Quality Index, Water Quality Index, and Environmental Quality Index on GRDP. The best model selection is done by Chow, Hausman, and Lagrange Multiplier tests. The regression equation of panel data used in this research is:

$$LnGRDP_{it} = \beta_0 - \beta_1 LnPOV_{it} - \beta_2 LnUR_{it} + \beta_3 LnHDI_{it} - \beta_4 LAQI_{it} - \beta_5 LnWQI_{it} - \beta_6 LnEQI_{it} + \varepsilon_{it}$$

Where GRDP is Gross Regional Domestic Product (Billion Rupiah), POV is Poverty Rate (Percent), UR is Unemployment Rate (Percent), HDI is Human Development Index, AQI is Air Quality Index, WQI is Water Quality Index, EQI is Environmental Quality Index, ε is Residual, β_0 is Intercept, $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$ is Regression Coefficient, t is periode and i is 10 Provinces in Sumatra Island and ln is natural logarithm.

RESULTS AND DISCUSSION

Panel Data Regression Classic Assumption Test

Classical assumption testing in panel data regression is very important to ensure the accuracy of the analysis. Which classical assumption test consists of normality test, multicollinearity test and heteroscedasticity test.

Table 1. Classical Assumption Test Results

Test	Results	Conclusion
Normality	Prob. *Jarque-Bera* 0.094523 > 0,05	Passed Test
Multicollinearity	No absolute correlation coefficient value exceeds 0.8	Passed Test

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Test	Results	Conclusion
Heteroscedasticity	Residual values do not cross the limits of 500 and -500	Passed Test

Source: processed data using Eviews12

Table 1. shows that this study has passed the normality test which indicates that the residuals are normally distributed. Then it has also passed the multicollinearity test which means that there is no multicollinearity between the independent variables. And passed the heteroscedasticity test which shows that there are no symptoms of heteroscedasticity in this study.

Selection of Panel Data Regression Model

Table 2. Chow test

Effect Test	Statistic	d.f	Prob.
Cross-section F	7683.023304	(9,104)	0.0000
Cross-section Chi-square	780.132599	9	0.0000

Source: processed data using Eviews12

Table 2. shows that the FEM model is better than the CEM in this chow test, because the value of the prob. F statistic 0.000 <0.05 so that H_0 is rejected.

Table 3. Hausman Test

Test Summary	Chi-Sq. Statistic	Chi-Sq.d.f	Prob.
Cross-Section Random	13.675264	6	0.0335

Source: processed data using Eviews12

Table 3. shows that prob. Chi-Square worth 0.0335 <0.05 concluded that H_0 is rejected so that the fixed effect model is more appropriate to use than the random effect model.

Hypothesis testing analysis

Table 4. Panel data regression processing results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-8.183580	1.030605	-7.940557	0.0000
POV	-0.153206	0.059677	-2.567241	0.0117
UR	0.045693	0.015906	2.872615	0.0049
HDI	5.048332	0.220977	22.84552	0.0000

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Variable	Coefficient	Std. Error	t-Statistic	Prob.
AQI	-0.186144	0.038907	-4.784368	0.0000
WQI	-0.070204	0.34138	-2.056483	0.0422
EQI	0.017021	0.054264	0.313666	0.7544
R-squared	0.999057			
Adjusted R-squared	0.998920			
F-statistic	7341.711			
Prob(F-statistic)	0.000000			

Source: processed data using Eviews12

Based on the results of data processing using panel data regression, the regression equation is obtained as shown in the table :

$$LnGRDP_{it} = -8.183 - 0.153LnPOV_{it} + 0.045LnUR_{it} + 5.048LnHDI_{it} - 0.186LAQI_{it} - 0.070LnWQI_{it} + 0.017LnEQI_{it} + \varepsilon_{it}$$

The equation above shows a constant value of -8.18357968097, which means that the GRDP in Sumatra Island in the last 12 years is -8.18357968097 where the variables Poverty Rate, Unemployment Rate, Human Development Index, Air Quality Index, Water Quality Index, Environmental Quality Index are considered constant. Whereas, the coefficient value of Poverty Rate variable on GRDP in Sumatera Island is -0.1532, which indicates that every increase in poverty by 1 percent will reduce GRDP by 0.1532 percent, assuming other variables are constant. Meanwhile, the coefficient for the Unemployment Rate is 0.0457, which means that a 1 percent increase in unemployment has the potential to increase GRDP by 0.0457 percent. The Human Development Index (HDI) has a coefficient of 5.0483, which indicates that a 1 percent increase in HDI can increase economic growth by 5.0483 percent. In contrast, the Air Quality Index (AQI) shows a coefficient of -0.1861, meaning that a 1 percent increase in AQI causes a decrease in GRDP by 0.1861 percent. The Water Quality Index (WQI) has a coefficient of -0.0702, indicating that a 1 percent increase in WQI will reduce GRDP by 0.0702 percent. Finally, the Environmental Quality Index (EQI) has a coefficient of 0.0170, but it is not significant, so a 1 percent increase in EQI only has the potential to increase GRDP by 0.0170 percent, assuming other variables remain constant.

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Hypotesis test

Based on the results of the t-test, it shows that Poverty Rate has a t-statistic of -2.5672 and a probability of 0.0117, which is less than alpha 0.05, so H_0 is rejected and Ha is accepted; this means that poverty has a significant effect on GRDP in Sumatra Island. For unemployment, the t-statistic is 2.8726 with a probability of 0.0049, also below alpha 0.05, which indicates a significant effect on GRDP. The Human Development Index (HDI) shows a t-statistic of 22.8455 and a probability of 0.0000, confirming a significant influence on GRDP. The Air Quality Index (AQI) has a t-statistic of -4.7844 and a probability of 0.0000, indicating a significant influence. The Water Quality Index (WQI) with a t-statistic of -2.0565 and a probability of 0.0422 also shows a significant effect. In contrast, the Environmental Quality Index (EQI) has a t-statistic of 0.3137 and a probability of 0.7544, which is greater than alpha 0.05, so H_0 is accepted and Ha is rejected, indicating that EQI has no significant effect on GRDP in Sumatra Island.

Meanwhile, based on the results of the t-test, it shows that a statistical F value of 7341.711 with a probability of 0.000000, which is smaller than 0.05. This indicates that at a significance level of 95%, the null hypothesis (H_0) is rejected and the alternative hypothesis (H1) is accepted. Thus, it can be concluded that all independent variables analyzed in this study have a significant effect simultaneously on GRDP in Sumatra Island.

Furthermore, based on the results of the coefficient of termination (R2) show that coefficient of determination (R^2) is 0.998920. This value indicates that 99.89 percent of the variables of poverty, unemployment, Human Development Index (HDI), Air Quality Index (AQI), Water Quality Index (WQI), and Environmental Quality Index (EQI) contribute to GRDP in 10 provinces in Sumatra Island, while the remaining 0.11 percent is influenced by other factors outside this research model.

Discussion

The Effect of Poverty on GRDP in Sumatera Island

The results showed that the poverty variable has a negative and significant impact on Gross Regional Domestic Product (GRDP) in Sumatra Island, with a coefficient of -0.153. This finding indicates that every one percent increase in poverty will cause a decrease in

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GRDP by 0.153 percent. When people are unable to purchase goods and services, aggregate demand declines, which in turn affects overall economic output. In the long run, a decline in consumption can result in a more significant decline in economic output, impacting GRDP. This finding is in line with the economic principle that poverty and economic growth are interrelated in a complex cycle. Previous research, such as that conducted by Hannyfah et al. that poverty has a significant negative impact on GRDP in 34 provinces in Indonesia during the 2019-2021 period reinforces the argument that the higher the poverty rate, the lower the GRDP obtained (Hannyfah et al., 2023). Poverty has a negative effect on economic growth because it limits people's access to resources needed to increase productivity (Pradana & Fitriyanti, 2022).

Furthermore, the high poverty rate in Sumatra Island also affects key economic sectors, such as agriculture and small industries that rely heavily on local labor. Limited access to education and health due to poverty reduces the quality of human resources, which in turn affects the productivity and competitiveness of the region's economy. In the context of endogenous growth theory, this suggests that investment in human capital and innovation is critical to driving long-term economic growth. The inability of a society to invest in education and training creates a cycle of poverty that is difficult to break.

As a strategic step in overcoming poverty and inequality, strengthening income distribution policies needs to be a top priority, especially in sustainable economic development in Sumatra Island. Improving access to education and health plays an important role in improving the quality of human resources, which in turn is the key to long-term economic growth in accordance with the principles of endogenous growth theory. As people's quality of life improves, not only does GRDP increase, but also the potential for innovation and productivity grows, creating a sustainable positive impact on the regional economy.

The Effect of Unemployment Rate on GRDP in Sumatera Island

The results show that unemployment has a positive and significant influence on Gross Regional Domestic Product (GRDP) in Sumatra Island, with a coefficient of 0.045. This finding seems contradictory to conventional economic theory, which generally assumes that unemployment has a negative impact on economic growth. However, in certain

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contexts, an increase in unemployment does not always imply a decrease in economic activity. For example, although Hannyfah et al. found that unemployment has a negative and significant effect on GRDP in 34 provinces in Indonesia (Hannyfah et al., 2023), another study by Sofiatus showed that GRDP has a positive relationship with the number of unemployed in Malang City (Sofiatus, 2017). This is in line with the findings of Geli et al. who also noted the positive influence of GRDP on the open unemployment rate in Flores Regency (Geli et al., 2021).

The relationship between unemployment and GRDP can be analyzed through the lens of Boserup's theory, which emphasizes that population growth can encourage the adoption of more intensive agricultural systems and innovations in the economic sector. According to Boserup, population growth can trigger the adoption of more advanced technologies, where innovations emerge and only become beneficial when the population reaches a certain level (Boserup, 2013). In this context, an increase in unemployment can be understood as a phenomenon that is not always negatively correlated with GRDP, especially when the transition occurs from traditional sectors such as agriculture to more technology-intensive industrial or service sectors.

As the population increases, the need for products and services also increases, creating new employment opportunities in more productive sectors. This is in line with Boserup's view that innovation can increase worker productivity, but its implementation is only effective if the workforce is large enough. While unemployment may increase in the short term due to this transition, in the long term, productivity gains and innovations resulting from population growth can contribute to an increase in GRDP.

In Sumatra Island, this phenomenon is evident despite the high unemployment rate, GRDP still shows a positive trend. The transition from traditional agriculture to industry and services often requires time for labor adjustment. During this transition period, individuals experience temporary unemployment, but they will eventually reintegrate into a more productive economy. Therefore, it is important to understand that unemployment does not necessarily reflect economic weakness but instead, it can be part of a process of structural change towards a more sustainable and productive economy. Nevertheless, it should be noted that a prolonged increase in unemployment can lead to a decline in consumption and

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productivity in the long run, which ultimately has a negative impact on GRDP. Thus, although the results show a positive influence between unemployment and GRDP, the government should still focus on creating quality jobs to maintain sustainable economic growth.

The Effect of Human Development Index on GRDP in Sumatera Island

The analysis shows that the Human Development Index (HDI) has a positive and significant influence on Gross Regional Domestic Product (GRDP) in Sumatra Island, with a coefficient of 5.048. That is, every one percent increase in HDI will contribute to an increase in GRDP by 5.048 percent. This positive relationship is in line with the economic literature which shows that investment in human resource development, especially through improving access to education and health, has a direct effect on economic growth. An increase in HDI is usually followed by an increase in GRDP because the main factors in HDI, namely education, life expectancy, and per capita income, affect labor capacity as well as economic competitiveness.

Within the endogenous growth theory, which emphasizes the critical role of investment in human capital and innovation as the main drivers of economic growth, these findings show significant relevance. The theory argues that improving the quality of human capital through education and health not only improves individual productivity, but also creates positive externalities that drive innovation and overall economic growth. Better education quality contributes to the creation of a more productive workforce, while optimal health conditions increase labor participation and operational efficiency. Therefore, improving the Human Development Index (HDI) in Sumatra Island can be viewed as a strategic step to strengthen the economic foundation of the region through the development of workforce quality, thus creating a broader positive impact on regional economic growth.

Research by Budihardjo et al. shows that HDI has a positive and significant influence on GRDP in the districts/cities of Central Java Province, supporting the argument that improving the quality of human resources has implications for increasing worker productivity and overall economic output (Budihardjo et al., 2020). This is supported by a statement from Jalil & Kamaruddin which says that a region that has a high HDI will produce a high economy (Jalil & Kamaruddin, 2018). In addition, a study by Sari and

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Setyowati also found that HDI has a positive effect on GRDP, suggesting that controlling HDI can encourage an increase in GRDP value (Sari & Setyowati, 2023). In Sumatra Island, an increase in HDI reflects people's access to better health and education facilities, which in turn improves the quality of the workforce.

Although the relationship between HDI and GRDP is positive, policies oriented towards improving HDI must be carefully designed so that the resulting growth is sustainable. Increased investment in human capital development, particularly through well-targeted education and health initiatives, is a key factor in driving Sumatra's future economic growth. Thus, policies that support access to high-quality education and health services will not only improve HDI, but also strengthen long-term economic growth in accordance with the principles of endogenous growth theory.

The Effect of Air Quality Index on GRDP in Sumatera Island

The findings of this study show that the Air Quality Index (AQI) has a significant negative effect on Gross Regional Domestic Product (GRDP) in Sumatra Island, with a coefficient of -0.186. This indicates that a decrease in air quality directly reduces economic output in the region. This is in line with research by Inayati et al. that the air quality index negatively affects GRDP at a significance level of 0.05 (Inayati & Febriani, 2024). Air pollution has the potential to reduce worker health, which in turn reduces efficiency and productivity. Prolonged exposure to pollution, especially in urban and industrial areas, can lead to respiratory and cardiovascular diseases, thus reducing the ability of the workforce to work optimally.

This phenomenon can be analyzed through the Environmental Kuznets Curve (EKC) theory, which explains the relationship between economic growth and environmental degradation. The Environmental Kuznets Curve hypothesizes that in the early stages of growth, biodiversity tends to suffer and in the later stages will decline (Matthews, 2018). The theory states that in the early stages of economic growth, increased economic activity is often accompanied by increased pollution and environmental degradation. However, after reaching a certain point in economic development, awareness of the importance of environmental quality increases, and better policies and technologies are implemented to reduce these negative impacts. In other words, the relationship between economic growth

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and environmental quality can be described as an inverted U-shaped curve where pollution increases with economic growth in the early stages, but then decreases as people reach higher income levels and begin to prioritize environmental sustainability.

While the results of this study show the negative impact of air quality on GRDP, it also reflects the challenges faced by Sumatra Island in transitioning towards more sustainable growth. Sectors such as the palm oil industry, coal, and agriculture are particularly vulnerable to the negative impacts of air pollution. Environmental damage caused by pollution can reduce the production efficiency and competitiveness of these sectors. In the context of EKC, while economic growth may result in increased pollution at an early stage, it is important to remember that with the implementation of stricter pollution control policies and investment in green technologies, the region can reach a turning point where economic growth is no longer detrimental to environmental quality.

Stricter air pollution control policies are needed to maintain a balance between economic growth and environmental quality. Transitioning to a greener economy through increased investment in green technology and renewable energy can also help mitigate the negative impact of air pollution on Sumatra's economy. Thus, while there is currently a negative relationship between KPI and GRDP, the implementation of sustainable development strategies can facilitate a shift towards a more balanced pattern of growth between economic and environmental aspects, in accordance with the principles of EKC.

The Effect of Water Quality Index on GRDP in Sumatera Island

This study found that water quality has a significant negative effect on Gross Regional Domestic Product (GRDP) in Sumatra Island, with a coefficient of -0.070. A decline in water quality shows a detrimental impact on economic activity, especially in the agriculture and fisheries sectors that rely heavily on clean water supply for irrigation and ecosystem habitat. Water pollution can reduce productivity in these sectors, causing a decrease in production output which has a direct impact on GRDP. This is in line with research by Damayanti (2016), which shows that poor water quality contributes to decreased public health and increased production costs, all of which negatively impact economic output. The Environmental Kuznets Curve (EKC) theory states that at the beginning of economic growth, economic activity often leads to increased pollution,

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including water pollution. However, as the economy grows, people begin to realize the importance of environmental quality and implement better policies and technologies to reduce negative impacts. Thus, this relationship forms an inverted U-shape, meaning that pollution increases in the early stages, but decreases as people's income increases and environmental sustainability becomes a priority. This suggests that improvements in water quality can support sustainable GRDP growth.

In Sumatra Island, the degradation of water quality due to pollution reflects the challenges faced in the development process. The agricultural sector, which accounts for a large portion of GRDP, is highly dependent on clean water supply. In the context of EKC, while economic growth may lead to an increase in water pollution at an early stage, it is important to remember that with the implementation of stricter pollution control policies and investment in environmentally friendly technologies, the region can reach a turning point where economic growth is no longer detrimental to environmental quality.

Therefore, stricter water pollution control policies are necessary to maintain a balance between economic growth and environmental quality. A transition to a more sustainable economy through increased investment in green technologies and better natural resource management could also help mitigate the negative impacts of water pollution on Sumatra's economy. Thus, while there is currently a negative relationship between water quality and GRDP, the implementation of sustainable development strategies can facilitate a shift towards a more balanced growth pattern between economic and environmental aspects in accordance with the principles of the Environmental Kuznets Curve (EKC).

The Effect of Environmental Quality Index on GRDP in Sumatera Island

The results show that the Environmental Quality Index (EQI) has no significant influence on Gross Regional Domestic Product (GRDP) in Sumatra Island, with a coefficient of 0.017 and a probability value of 0.754. This finding indicates that the EQI, which is a composite of environmental factors such as air, water and land quality, may not have been a major determinant of Sumatra's economic growth over the past 12 years. Sumatra's economy is still dominated by extractive sectors such as mining, oil palm plantations, and heavy industry that often do not prioritize environmental sustainability. As a result, while environmental quality is deteriorating, the direct impact on GRDP has yet to be seen in

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any significant way.

This phenomenon can be analyzed through the Environmental Kuznets Curve (EKC) theory, which explains the relationship between environmental quality indices and economic growth. According to the EKC theory, in the early stages of economic growth, increased economic activity often leads to further environmental degradation. However, after reaching a certain point in economic development, when per capita income increases, people begin to realize the importance of environmental quality and implement better policies and technologies to reduce these negative impacts. In other words, the relationship between environmental quality indices and economic growth can be described as an inverted U-shaped curve, where environmental degradation increases along with economic growth in the early stages but then decreases as people achieve awareness and capacity to better manage the environment.

In Sumatra Island, the environmental quality index and environmental degradation have an impact on GRDP and economic growth. The dominance of extractive sectors that are not environmentally friendly can cause environmental degradation that impacts the regional economy. These sectors often ignore the long-term impacts on ecosystems and public health. While environmental degradation may not immediately hamper production or economic growth in the short term, it can reduce agricultural productivity, public health, and investment attractiveness in the long term. This suggests that while the current impact of environmental quality indices on GRDP appears weak, environmental policies that are not integrated with economic development strategies could have serious consequences in the future.

Previous research shows that environmental quality has a positive effect on economic growth, signaling that improving environmental quality can encourage economic growth (Claudia & Nugrahadi, 2024). Therefore, although the results of this study show that EQI has no significant effect on current GRDP, it is important for the government and policy makers to pay attention to environmental quality as a long-term investment in economic development. By implementing stricter policies to protect environmental quality and encourage sustainable development practices, Sumatra could reach a turning point in the

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Environmental Kuznets curve where economic growth will begin to align with improvements in environmental quality.

CONCLUSION

Based on the results of the study, it shows that partially each variable of poverty, unemployment, Human Development Index, The Air Quality Index (AQI), Water Quality Index (WQI) has a significant effect on GRDP. While, in contrast, the Environmental Quality Index (EQI) has has no significant effect on GRDP in Sumatra Island. Meanwhile, based on the results of the t-test, it shows that poverty, unemployment, human development index, air quality index (AQI), water quality index (WQI), and environmental quality index (EQI) analyzed in this study have a significant effect simultaneously on GRDP in Sumatra Island.

This study underscores the complex interplay between social, economic and environmental factors in shaping Sumatra's economic resilience. Poverty and environmental degradation negatively impact GRDP, while human capital development significantly improves economic performance. Policymakers should adopt a multidimensional approach that integrates poverty alleviation, environmental sustainability and human capital investment to promote long-term economic resilience. In addition, the findings suggest that policy interventions should focus on labor market transition, pollution control, and sustainable resource management.

LIMITATION AND RECOMMENDATION

This study has several limitations that may affect the interpretation of the results. One potential limitation is the measurement accuracy of the environmental quality variables, which may not fully capture local variations in air and water pollution. In addition, changes in economic policies at the national and regional levels may affect trends in GRDP, introducing potential bias in the analysis. Future research should explore additional variables, such as the impact of climate change, trade policies, and technological advancements, to improve the understanding of economic dynamics in Sumatra. In addition, the application of this research framework to other regions with similar economic structures could validate these findings and provide broader policy insights.

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