“Sectoral public spending, human development, and income inequality in North Sumatra province: District-level evidence from Indonesia”

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SECTORAL PUBLIC SPENDING, HUMAN DEVELOPMENT, AND INCOME INEQUALITY IN NORTH SUMATRA PROVINCE: DISTRICT-LEVEL EVIDENCE FROM INDONESIA

Abstract

This study examines whether district-level public expenditures on education, health, and infrastructure enhance human development and reduce income inequality across 33 regencies/municipalities in North Sumatra Province, Indonesia. The study is situated within the context of fiscal decentralization, where local government spending is expected to improve basic service provision, yet substantial territorial disparities in welfare outcomes and fiscal capacity remain. Using balanced panel data over the short 2021–2023 period, this study applies descriptive regional mapping, Hodrick–Prescott trend filtering, and panel regression models. Model selection is conducted using the Chow, Hausman, and Lagrange Multiplier tests. The trend analysis indicates positive associations between basic service expenditures and the Human Development Index (HDI), with infrastructure expenditure showing the strongest trend correlation, followed by health and education expenditures. However, the preferred random effects model reveals that education and infrastructure expenditures have positive but statistically insignificant effects on HDI, while health expenditure shows a negative and statistically insignificant coefficient. Poverty exerts a statistically significant negative effect on HDI, highlighting structural deprivation as a key constraint on human development. For income inequality, the preferred fixed effects model shows that infrastructure expenditure significantly reduces the Gini index, while GRDP per capita also has a significant inequality-reducing effect. These findings suggest that increasing public expenditure alone is insufficient to achieve inclusive development. Fiscal policy must therefore prioritize expenditure quality, spatial targeting, and implementation capacity to transform public budgets into equitable improvements in human development and income distribution.

Keywords expenditure, inequality, human development, poverty, infrastructure, decentralization

JEL Classification H72, I31, D63, R58

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INTRODUCTION

Sustainable regional development depends on the capacity of subnational governments to allocate public resources efficiently, equitably, and in ways that generate long-term improvements in social welfare (Liu, 2024). In decentralized fiscal systems, local governments assume a central role in delivering basic public services, particularly in education, health, and infrastructure. These sectors are fundamental to human capital formation (Adan & Ahmed, 2026), labor productivity, access to health services (Yang et al., 2022), and distributive outcomes (Ain et al., 2025). Fiscal federalism suggests that decentralization can enhance allocative efficiency when local governments possess better information about local needs and preferences than central authorities (Alonso & Andrews, 2019). However, fiscal decentralization may

also reproduce or even deepen inequality when regions differ substantially in fiscal capacity, administrative capability, geographic conditions, and economic structure.

Indonesia provides an interesting empirical setting for examining this issue. The country's decentralization framework grants districts and municipalities substantial authority in public service delivery. Nevertheless, welfare outcomes remain spatially uneven. Improvements in national human development indicators may therefore conceal persistent disparities within provinces and across local jurisdictions. This gives rise to a central scientific problem: although decentralized expenditure is often designed as a mechanism for territorial equalization, its actual effectiveness depends on whether public spending is translated into measurable improvements in living standards and reductions in income inequality at the local level (Aritenang & Chandramidi, 2023; Susilo et al., 2026; Siburian, 2021).

North Sumatra Province offers a particularly relevant case for investigating the relationship between sectoral public expenditure, human development, and income inequality. The province is both economically significant and territorially diverse within Indonesia. It comprises highly urbanized municipalities, industrial and trade-oriented districts, agrarian and plantation-based regions, mountainous inland areas, and geographically isolated island territories, each characterized by distinct development constraints and public service needs. The eastern coastal corridor, including Medan and its surrounding areas, functions as a major economic, administrative, and commercial hub, while many rural districts remain strongly dependent on agriculture, plantations, fisheries, and non-farm rural livelihoods. Agriculture continues to make an important contribution to provincial output and employment, although rural transformation has also encouraged diversification toward high-value commodities and non-agricultural activities (Novita et al., 2022). At the same time, North Sumatra exhibits pronounced spatial disparities in human development, particularly in educational infrastructure, school participation, and regional education across its 33 districts and municipalities (Harahap et al., 2024). Urban centers generally benefit from better infrastructure and service accessibility, whereas mountainous and island districts face geographic barriers, weaker connectivity, and more limited public service provision (Rachmawati et al., 2023). The coexistence of urban growth poles, agricultural production centers, highland regions, and peripheral island economies makes North Sumatra an ideal case for assessing whether sector-specific public expenditures in education, health, infrastructure, and related sectors can improve human development and reduce income inequality under heterogeneous local conditions.

According to provincial data for North Sumatra released by BPS-Statistics Indonesia of North Sumatra Province (2026, 2023), the Human Development Index (HDI) increased from 75.13 in 2023 to 76.47 in 2025. However, this aggregate improvement masks substantial territorial disparities. In 2025, Medan City recorded an HDI of 83.74, while West Nias Regency recorded an HDI of 66.65, representing a gap of more than 17 index points. Urban areas such as Pematangsiantar and Tebing Tinggi consistently outperform peripheral districts such as Nias and South Nias, indicating that provincial-level progress does not necessarily translate into balanced territorial development.

Fiscal disparities mirror these welfare gaps. The fiscal data used in this study are derived from official regional budget data published by the Directorate General of Fiscal Balance (DJPK), Ministry of Finance of the Republic of Indonesia, and related official regional budget reporting systems. To ensure comparability across districts, education expenditure is expressed as per capita indicator, obtained by dividing district-level education-function expenditure by the corresponding district-level population denominator used in the empirical dataset. Based on this calculation, education expenditure in 2023 was estimated at approximately IDR 29.8 million per capita in Deli Serdang, compared with approximately IDR 1.47 million per capita in West Nias (our calculations based on DJPK (2023) and BPS-Statistics Indonesia of North Sumatra Province (2024)). These figures are reported as descriptive indicators of fiscal-spending intensity and should not be interpreted as direct measures of service quality, learning outcomes, or expenditure effectiveness. Health and infrastructure expenditures also vary sharply across districts. These

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differences suggest that regions with stronger economic bases are better positioned to allocate resources to human capital development and connectivity, whereas geographically constrained districts often face higher service-delivery costs and narrower fiscal space. This condition produces a spatial double disadvantage, in which lower fiscal capacity coincides with greater development needs.

Income inequality adds a further layer of complexity to this problem. Economically advanced areas may record higher welfare levels while simultaneously experiencing urban dualism, labor market segmentation, and unequal access to economic opportunities. Conversely, peripheral regions may display lower measured inequality not because development is more inclusive, but because economic opportunities are uniformly limited. Consequently, the relationship between public expenditure, living standards, and inequality cannot be adequately understood through aggregate provincial indicators alone. It requires district-level evidence capable of capturing local fiscal variation, development outcomes, and distributive effects within a unified analytical framework.

The scientific problem addressed in this paper is therefore whether decentralized sectoral expenditure functions as an effective equalizing instrument in a heterogeneous province, or whether its effects are weakened by poverty, fiscal disparities, implementation capacity, and spatially differentiated development conditions. This issue is highly relevant to public finance debates in developing decentralized economies, where the central policy question is not merely how much local governments spend, but whether such spending is effective, well-targeted, and capable of reducing structural welfare gaps.

1. LITERATURE REVIEW AND HYPOTHESES

This study builds upon the theoretical framework developed by Samuelson (1958), which argues that government intervention becomes necessary when market mechanisms fail to allocate certain goods and services in a socially optimal manner. This perspective is particularly relevant for examining public expenditure on education, health, and infrastructure, as these sectors are not merely administrative budget categories, but strategic instruments for expanding access, strengthening human capabilities, reducing spatial inequality, and improving welfare across regencies and municipalities. This framework is further refined by Matos et al. (2023), who emphasize that public spending should not be evaluated solely on the basis of fiscal inputs or budget realization, but also in terms of its translation into measurable outcomes and long-term social impacts.

Human capital theory also provides a central explanation for the expected relationship between education, health, and living standards. Becker (1962) conceptualizes education and health as investments embodied in individuals, while subsequent studies show that schooling, skills, and health conditions shape labor productivity (Patron et al., 2026; Hu & Liang, 2021). These mechanisms are closely linked to multidimensional welfare indicators such as the Human Development Index (HDI), which integrates longevity, education, and decent living standards (Hussien et al., 2025). Empirical evidence generally supports the positive role of education and health expenditure in improving human development, although the magnitude and timing of these effects vary across countries, regions, and institutional contexts (Kousar et al., 2023; Seran et al., 2025; Sumiyarti & Pratama, 2024).

However, the equalizing effect of human capital expenditure is conditional. Public spending on education and health may fail to reduce welfare gaps when allocations are concentrated primarily on physical inputs rather than learning and health outcomes, when facilities are unevenly distributed, or when poor households continue to face non-budgetary barriers to access (Dwiputrianti et al., 2026). In decentralized systems, intergovernmental transfers therefore do not automatically reduce educational or health inequality if allocation formulas do not adequately account for local needs, geographic constraints, and service delivery costs (Wirandana & Khoirunurrofik, 2024).

Infrastructure occupies a complementary but distinct position in regional development theory.

Infrastructure functions as an enabling input for both private capital and human capital by improving connectivity, reducing logistics costs, and expanding access to education, health services, labor markets, and trade networks (Brzozowski, 2023; Eid & Hayder, 2025; Frank & Martínez-Vázquez, 2015; Vidya & Taghizadeh-Hesary, 2021). It may reduce regional disparities by connecting lagging regions to broader economic opportunities. However, infrastructure investment may also reinforce agglomeration when it disproportionately benefits already developed areas (Mardianto & Fazaalloh, 2025; Stadoleanu & Neculita, 2025; Medeiros et al., 2022). Accordingly, the developmental effect of infrastructure depends not only on the scale of investment, but also on spatial targeting, maintenance quality, accessibility, and integration with human capital policies.

The literature on inequality further shows that fiscal policy can influence distribution through both direct redistribution and opportunity-enhancing expenditure. Public investment in education, health, and infrastructure can reduce long-term inequality when it expands access for low-income groups, improves employability, and connects peripheral areas to markets (Musibau et al., 2024; Darvas, 2020). Infrastructure is particularly relevant to regional inequality because it shapes mobility, market access, and the spatial distribution of economic activity. Empirical studies find that infrastructure can moderate interregional inequality and narrow household welfare gaps when investment is designed to reach underserved regions (Medeiros et al., 2021; Wan et al., 2024; Zolfaghari et al., 2020).

Poverty is also closely linked to human development and income inequality. It restricts household access to nutritious food, quality schooling, health services, sanitation, transportation, and productive assets. These constraints may reduce the effectiveness of public spending because households may be unable to convert the availability of public services into improved welfare outcomes. Evidence from multidimensional poverty studies shows that deprivation is associated with lower human development outcomes and persistent regional disparities (Goswami & Ghosal, 2022). Poverty should therefore be treated not only as a welfare outcome, but also as a structural constraint that can weaken the transmission of fiscal expenditure into improvements in HDI.

Previous studies on Indonesia and other decentralized economies provide important evidence, but three gaps remain based on latest evidences. First, many studies rely on national or provincial aggregates, which may obscure substantial intra-provincial variation. Second, several studies examine inequality and human development separately, thereby limiting understanding of whether public expenditure improves welfare and distributional outcomes simultaneously. Third, the spatially differentiated effectiveness of sectoral spending remains underexamined in provinces characterized by heterogeneous fiscal capacities, geographic conditions, and development structures. These gaps are important because local governments may allocate resources to similar budget categories but generate different outcomes depending on poverty levels, institutional capacity, and local economic structures.

Based on these gaps, this study aims to examine whether district-level expenditures on education, health, and infrastructure improve human development and reduce income inequality across 33 regencies and municipalities in North Sumatra Province, Indonesia. The following hypotheses are tested:

H1: Education expenditure has a positive effect on the Human Development Index.

H2: Health expenditure has a positive effect on the Human Development Index.

H3: Infrastructure expenditure has a positive effect on the Human Development Index.

H4: The poverty rate has a negative effect on the Human Development Index.

H5: Infrastructure expenditure has a negative effect on the Gini index.

H6: GRDP per capita has a negative effect on the Gini index.

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2. METHODS

This study employs balanced panel data covering 33 regencies/municipalities in North Sumatra Province over the period 2021–2023, yielding 99 district-year observations. A census approach is adopted because the analysis includes all regencies and municipalities within the province. The study period is selected because it represents the early post-COVID-19 normalization phase of local government spending and captured short- rapid responsiveness of independent variables on dependent variables to policy shifts. Beside of that, this timeframe considered comparable data on sectoral expenditure, the Human Development Index (HDI), the Gini index, poverty, and GRDP per capita are available for all regions.

The empirical procedure consists of five main steps. First, district-level data are compiled from Statistics Indonesia (BPS) and the Directorate General of Fiscal Balance (DJPK), Ministry of Finance of the Republic of Indonesia. Second, education, health, and infrastructure expenditures are transformed into per capita indicators to improve comparability across districts and municipalities. Third, descriptive regional mapping and Hodrick–Prescott (HP) trend filtering are applied to identify structural patterns and associations between basic service expenditure and HDI. Given the relatively short observation period, the HP filter is used strictly as a descriptive smoothing technique and not as evidence of causal relationships. Fourth, panel regression models are estimated to examine the relationship between sectoral public expenditure and the two dependent variables. Fifth, model selection is conducted using the Chow test, Hausman test, and Lagrange Multiplier test, following standard panel data procedures (Aksentijević et al., 2021; Wooldridge, 2020).

Two empirical models are estimated. The first model examines the effects of education, health, and infrastructure expenditure, together with poverty, on HDI. The second model investigates the effects of infrastructure expenditure and GRDP per capita on income inequality. Both fixed effects and random effects estimators are considered because local jurisdictions may differ in unobserved characteristics, including geographic conditions, administrative capacity, service delivery quality, and economic structure. The fixed effects estimator controls for time-invariant unobserved heterogeneity when such characteristics are correlated with the explanatory variables, whereas the random effects estimator provides a more efficient specification when unobserved regional effects are uncorrelated with the regressors. Table 1

Table 1. Variable definitions

Variable	Definition	Measurement / Unit	Data source
Human Development Index (HDI)	Dependent variable representing living standards through health, education, and decent standard of living dimensions.	HDI value at district/municipality level, scale 0–100, 2021–2023	Statistics Indonesia (BPS)
Gini index	Dependent variable representing income inequality	Gini index at district/municipality level, scale 0–1, 2021-2023	Statistics Indonesia (BPS)
Education expenditure	Regional government expenditure allocated to the education function as a basic public service	Education function expenditure per capita, calculated from realized budget expenditure divided by population	Directorate General of Fiscal Balance (Direktorat Jenderal Perimbangan Keuangan/DJPK), Ministry of Finance
Health expenditure	Regional government expenditure allocated to the health function	Health function expenditure per capita at district/municipality level	Directorate General of Fiscal Balance (Direktorat Jenderal Perimbangan Keuangan/DJPK), Ministry of Finance
Infrastructure expenditure	Regional government expenditure for roads, bridges, irrigation, and other basic physical facilities supporting economic activity and access to services	Infrastructure expenditure per capita, based on public works and related infrastructure expenditure	Directorate General of Fiscal Balance (Direktorat Jenderal Perimbangan Keuangan/DJPK), Ministry of Finance
GRDP per capita	Average economic output per resident within a region	GRDP per capita at constant prices, million rupiah per person	Statistics Indonesia (BPS)
Poverty rate	Share of population living below the poverty line	Percentage of poor population at district/municipality level	Statistics Indonesia (BPS)

Note: HDI = Human Development Index; GRDP = Gross Regional Domestic Product.

presents the definitions, measurements, and data sources for the variables under study.

The estimated equations are specified as follows:

$$\ln\left(HDI\right)_{it} = \alpha + \beta_1 \ln\left(EDU\right)_{it} + \beta_2 \ln\left(HEALTH\right)_{it} + \beta_3 \ln\left(INFRA\right)_{it} + \beta_4 POV_{it} + \varepsilon_{it}, \quad (1)$$

$$GINI_{it} = g + q_1 \ln\left(INFRA\right)_{it} + q_2 \ln\left(CAP\right)_{it} + m_{it}. \quad (2)$$

where *HDI* denotes the Human Development Index, *EDU* is education expenditure, *HEALTH* is health expenditure, *INFRA* is infrastructure expenditure, *POV* is the poverty rate, *CAP* is GRDP per capita, *i* denotes the district/municipality, *t* denotes the year, and epsilon is the error term. Expenditure variables and GRDP per capita are expressed in natural logarithms to reduce scale differences and allow elasticity-based interpretation.

3. RESULTS

The results are presented in two stages. The first stage reports descriptive trend associations between sectoral expenditure and HDI using HP-filtered series. The second stage reports panel regression estimates for the HDI and Gini index models, including model selection tests and hypothesis testing.

To strengthen the descriptive analysis, the Hodrick–Prescott (HP) trend filtering approach is applied to the observed series. The HP filter is widely used in applied economic analysis to separate a time series into a smooth long-term trend component and a short-term cyclical component (Maranzano & Pelagatti, 2025). In this context, the filtered trend reduces short-run fluctuations and allows the underlying association between sectoral expenditure and HDI to be observed more clearly. Following the logic of trend-cycle decomposition, the HP-filtered series is useful for identifying whether changes in education, health, and infrastructure expenditure move in a direction that is descriptively consistent with improvements in human development.

Figure 1 shows a positive trend association between education expenditure and HDI. The estimated correlation is approximately 0.33, indicating a moderate relationship. The upward trend suggests that districts and municipalities with higher education expenditure tend to record higher HDI values. The estimated slope indicates that an increase of approximately IDR 100 billion of education expenditure is associated with an increase of about 0.4 points in HDI. This pattern supports the expected direction of *H1* descriptively, although causal inference requires panel regression testing.

Figure 2 presents the trend association between health expenditure and HDI. The correlation between the filtered components is approximately

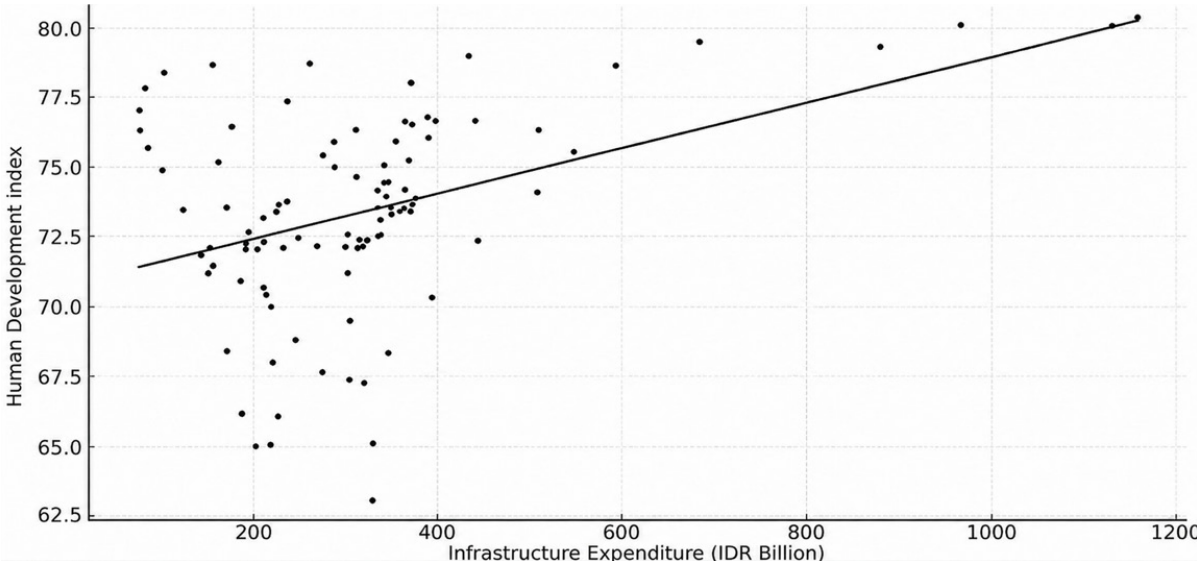

Figure 1. Education expenditure and Human Development Index

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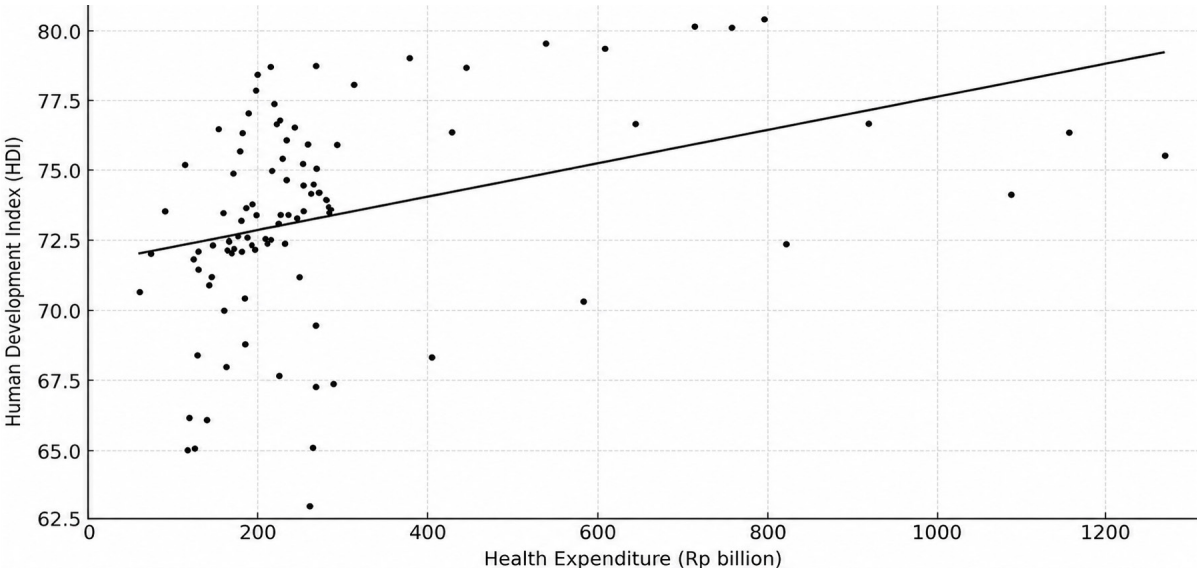

Figure 2. Health expenditure and Human Development Index

0.37, with a coefficient of determination near 0.14. The estimated slope implies that an increase of approximately IDR 100 billion is associated with an increase of around 0.6 points in HDI. This result is consistent with the expected direction of *H2* at the descriptive level.

Figure 3 shows the strongest descriptive association. Infrastructure expenditure has a trend correlation of approximately 0.42 with HDI, with a coefficient of determination around 0.17. The estimated slope suggests that an increase of approximately IDR 100 billion infrastructure expenditure is associated with an increase of around 0.8 points in HDI. This indicates that infrastructure may be the sector most closely related to spatial differences in human development. This result also consistent with the expected direction of *H3* at the descriptive level.

Panel regression is then used to test the hypotheses more formally. Table 2 reports the estimation results for the HDI model. The Chow test rejects the common effects model, and the Lagrange multiplier test confirms the presence of panel effects. The Hausman test does not reject the random effects specification, indicating that the random effects model is the preferred estimator for the HDI model.

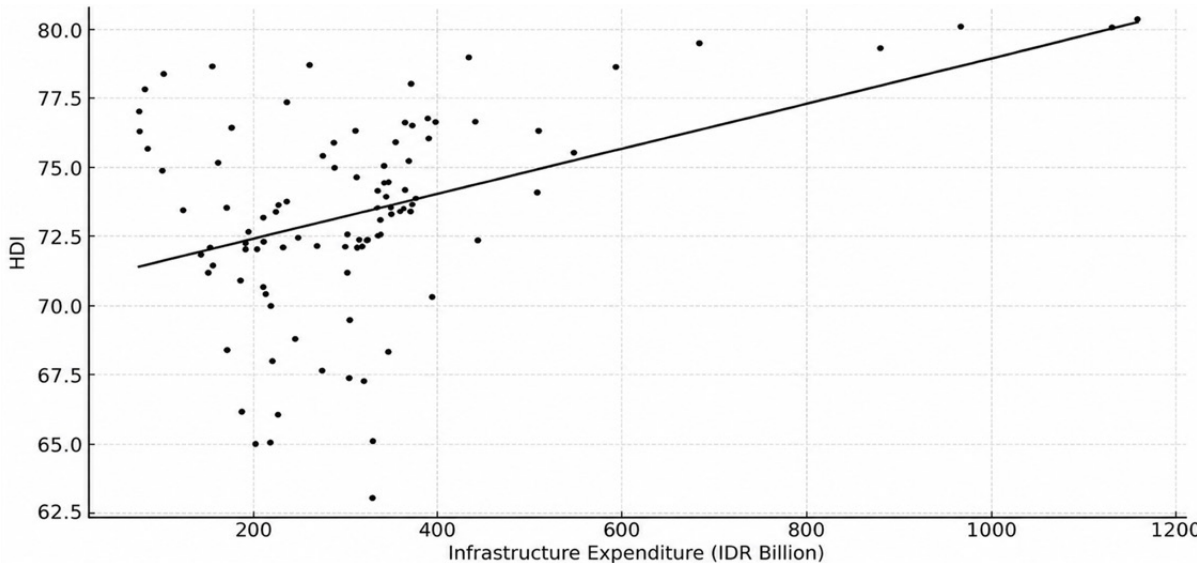

Figure 3. Infrastructure expenditure and Human Development Index

Table 2. Panel regression results for Human Development Index

Variable	Random effects model	Fixed effects model	Common effects model
C	4.382***	4.344***	4.377***
	(54.77)	(85.89)	(22.60)
ln(EDU)	0.003	0.004*	–0.006
	(0.916)	(1.77)	(–0.53)
ln(HEALTH)	–0.002	–0.001	0.009
	(–1.09)	(–1.24)	(0.83)
ln(INFRA)	0.001	0.001	–0.001
	(0.09)	(0.78)	(–0.15)
POV	–0.001***	–0.012***	–0.011***
	(–13.18)	(–18.22)	(–11.13)
Adjusted R2	0.708	0.998	0.635
Hausman test	0.755		
	Prob. 0.944		
Chow test		456.71***	
		Prob. 0.000	
Lagrange multiplier test	92.841***		
	Prob. 0.000		

Note: t-statistics are shown in parentheses. *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Education expenditure has a positive coefficient, but the effect is not statistically significant. Therefore, *H1* is not statistically supported. Health expenditure has a negative but statistically insignificant coefficient, meaning that *H2* is rejected by the panel regression results. Infrastructure expenditure has a positive but statistically insignificant coefficient, so *H3* is also not statistically supported. In contrast, the poverty rate has a negative and statistically significant coefficient, supporting *H4*. The adjusted R^2 of 0.708 indicates that the model explains approximately 70.8% of the variation in HDI across districts/municipalities and years.

Table 3 presents the income inequality model. The Chow test rejects the common effects model, the Lagrange multiplier test supports the presence of panel effects, and the Hausman test indicates that the fixed effects estimator is preferred to the random effects estimator. Therefore, the fixed effects model is used to interpret the determinants of the Gini index.

Infrastructure expenditure has a negative and statistically significant coefficient of –0.230, supporting *H5*. This indicates that higher infrastructure expenditure is associated with a lower Gini index

Table 3. Panel regression results for income inequality

Variable	Random effects model	Fixed effects model	Common effects model
C	0.287	4.328***	0.056
	(1.08)	(6.90)	(0.28)
ln(INFRA)	–0.001	–0.230***	0.001
	(–0.81)	(–6.25)	(0.95)
ln(CAP)	0.001	–0.016***	0.010
	(0.07)	(–5.18)	(0.95)
Adjusted R2	0.007	0.963	0.010
Hausman test	7.338**		
	Prob. 0.026		
Chow test		25.97***	
		Prob. 0.000	
Lagrange multiplier test	25.502***		
	Prob. 0.000		

Note: t-statistics are shown in parentheses. *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

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after controlling for district-specific fixed effects. GRDP per capita also has a negative and statistically significant coefficient of –0.016, supporting *H6*. The adjusted R^2 of 0.963 indicates that the model explains approximately 96.3% of the variation in income inequality across districts/municipalities and years. Overall, the results show that infrastructure expenditure and regional income levels are more strongly associated with inequality reduction than sectoral expenditure is with short-run HDI improvement.

4. DISCUSSION

The empirical findings reveal an important distinction between descriptive associations and short-run econometric effects. The descriptive trend analysis suggests that education, health, and infrastructure expenditures are positively associated with the Human Development Index (HDI). However, the panel regression results indicate that these sectoral expenditures do not exert statistically significant short-run effects on HDI during the 2021–2023 period. This divergence should not be interpreted as evidence that sectoral public expenditure is irrelevant to human development. Rather, it suggests that the relationship between public spending and human development is likely to operate through longer and more complex transmission mechanisms. Annual budget fluctuations within a short observation window may be insufficient to generate observable changes in composite welfare indicators such as HDI, which incorporate dimensions that typically evolve gradually over time. This interpretation is consistent with previous studies emphasizing that the effects of education and health expenditure on human development are often mediated by institutional quality, governance effectiveness, service delivery capacity, and the lagged nature of human capital formation (Hadipour et al., 2023; Hasnat, 2025; Kousar et al., 2023; Sagarik, 2023).

The statistically insignificant coefficient of education expenditure requires careful interpretation. It does not imply that education is unimportant for human development. Instead, it indicates that the magnitude of district-level education expenditure alone is not sufficient to explain short-run variation in HDI across regencies and municipalities. One plausible explanation is that education spending may be largely absorbed by recurrent expenditure, including personnel costs, routine administration, and maintenance of physical facilities, rather than being directly translated into improvements in learning quality, school completion, equitable access, or educational achievement. In such a context, the developmental effect of education expenditure depends less on nominal budget size and more on expenditure composition, targeting accuracy, and the capacity of local governments to convert fiscal resources into educational outcomes. This argument is consistent with Miranda-Lescano et al. (2023) and Ruzima and Veerachamy (2023), who suggest that public spending may have limited effects on human development when its allocation and utilization are not sufficiently outcome-oriented. It also aligns with evidence from Indonesia showing that intergovernmental transfers do not automatically reduce educational inequality when allocation mechanisms and service delivery conditions remain uneven across regions (Wirandana & Khoirunurrofik, 2024).

The negative but statistically insignificant coefficient of health expenditure should also be interpreted with caution. During the study period, local health budgets may still have reflected post-pandemic fiscal adjustments, emergency-related spending, or transitional allocations associated with the normalization of public services after COVID-19. Moreover, the health component of HDI, particularly life expectancy, is structurally slow-moving and influenced by a wide range of determinants beyond public health expenditure alone. These include nutrition, sanitation, access to clean water, environmental quality, health-seeking behavior, service quality, and household socio-economic conditions. Therefore, the absence of a statistically significant short-run effect does not contradict the human capital perspective on health investment. Instead, it highlights that health expenditure affects human development through indirect, cumulative, and quality-dependent pathways. The result suggests that the effectiveness of health spending depends not only on the volume of fiscal allocation, but also on program design, preventive health orientation, service accessibility, and the ability of poor and geographically remote households to utilize available health services (Yormirzoev & Ayombekova, 2025).

Infrastructure expenditure presents a more direct empirical pattern. It shows the strongest descriptive association with HDI and has a statistically significant negative effect on income inequality. This finding supports the theoretical view by Medeiros et al. (2022) that infrastructure functions as both a productive input and a spatial equalizer. Infrastructure can reduce regional inequality by improving physical connectivity, lowering transaction and transportation costs, expanding market access, and increasing household mobility. It also strengthens access to education, health facilities, employment opportunities, and trade networks, particularly in geographically constrained and underserved areas. In a province such as North Sumatra, where urban centers, highland districts, agricultural regions, and island territories coexist, infrastructure investment may play a particularly important role in reducing spatial exclusion. Moreover, infrastructure policy also strengthen interregional logistics and farmer-oriented transport systems across North Sumatra to improve the efficient distribution of agricultural products from rural production centers to urban markets. This finding is consistent with empirical studies showing that infrastructure investment can narrow urban-rural welfare gaps, improve regional connectivity, and reduce income inequality when it is directed toward lagging regions and integrated with broader development policies (Medeiros et al., 2021; Wan et al., 2024; Zolfaghari et al., 2020).

The statistically significant negative effect of poverty on HDI represents one of the most substantively important findings of this study. Poverty constrains human development through multiple channels. Poor households often face limited access to nutritious food (Javier et al., 2024), quality education (Panyi et al., 2025), health services (Bidmead et al., 2024), adequate housing (Kim et al., 2022), sanitation (Ozughalu & Ozughalu, 2026), digital connectivity (Boerkamp et al., 2024), and productive assets (Liu et al., 2023). These constraints reduce their ability to benefit from public services even when such services are formally available. In this sense, poverty functions not only as an outcome of underdevelopment, but also as a structural barrier that weakens the transmission of public expenditure into human development gains. Considering North Sumatra's spatial development disparities, poverty alleviation and regional development policies should prioritize areas beyond Medan and its surrounding districts to avoid excessive concentration around the provincial capital. The finding therefore suggests that sectoral spending policies must be complemented by poverty reduction strategies, targeted social protection, and improved access mechanisms for vulnerable households. Without such complementary interventions, public expenditure may have limited capacity to generate inclusive improvements in HDI. This interpretation is consistent with multidimensional poverty studies showing that deprivation is strongly associated with lower human development outcomes and persistent regional disparities (Goswami & Ghosal, 2022).

The negative association between GRDP per capita and the Gini index indicates that higher regional income is associated with lower income inequality in the preferred fixed effects model. This result may reflect the role of regional economic expansion in broadening employment opportunities, increasing local fiscal capacity, and improving household access to services and markets. Nevertheless, this relationship should not be interpreted as automatic or universally inclusive. Economic growth can reduce inequality only when its benefits are distributed across social groups and territories. In regions where growth is concentrated in capital-intensive sectors or urban centers, higher income may coexist with persistent inequality. Therefore, in the context of North Sumatra, the inequality-reducing effect of GRDP per capita should be understood as conditional upon the structure of regional growth, labor absorption, local value-chain participation, and the extent to which peripheral districts are connected to expanding economic opportunities. A practical policy direction is to develop locally based economic growth centers beyond the provincial capital, including district-level tourism hubs based on each region's comparative advantages and local commodity development programs aimed at improving product quality, processing capacity, and market readiness for wider domestic and cross-border markets, including nearby Malaysia. This strategy distribute economic opportunities more evenly across regions, strengthen local value chains, and reduce the risk that growth remains concentrated in Medan and its surrounding areas. This interpretation is in line

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with regional development literature emphasizing that growth becomes distributionally beneficial only when it is spatially inclusive and employment-generating (Temerbulatova et al., 2024).

The findings contribute to the fiscal decentralization literature by showing that decentralized public expenditure does not automatically produce improvements in human development or reductions in inequality. The effectiveness of decentralized spending depends on how fiscal resources are allocated, implemented, spatially targeted, and integrated with local development needs. In North Sumatra, infrastructure expenditure appears to have a more immediate and measurable association with inequality reduction, while education and health expenditures require stronger outcome orientation before their effects can be reflected in HDI improvements. Thus, the central issue in decentralized public finance is not merely whether local governments spend more, but whether they spend effectively, equitably, and in ways that transform fiscal resources into inclusive human development.

CONCLUSION

This study investigated whether district-level public expenditures on education, health, and infrastructure contribute to human development and income inequality reduction across 33 regencies and municipalities in North Sumatra Province, Indonesia. Drawing on balanced panel data for 2021–2023, the findings reveal a nuanced relationship between sectoral public expenditure, human development, and distributive outcomes. The descriptive trend analysis indicates that basic service expenditures are positively associated with the Human Development Index (HDI), with infrastructure expenditure showing the strongest association. However, the panel regression results demonstrate that education, health, and infrastructure expenditures do not exert statistically significant short-run effects on HDI. This suggests that the contribution of sectoral expenditure to human development may operate through lagged, cumulative, and institutionally mediated mechanisms rather than immediate annual budget effects. By contrast, poverty has a statistically significant negative effect on HDI, indicating that structural deprivation remains a major constraint on the improvement of living standards.

Regarding income inequality, the study finds that infrastructure expenditure and GRDP per capita have statistically significant negative effects on the Gini index. These results suggest that infrastructure investment can serve as an important redistributive development instrument when it improves connectivity, expands access to public services, facilitates market participation, and broadens employment opportunities. In territorially diverse provinces such as North Sumatra, infrastructure appears to play a particularly important role in linking peripheral and lagging regions to wider economic and social opportunities.

The main implication of this study is that higher public expenditure alone is insufficient to ensure inclusive human development. Fiscal policy must move beyond a budget-expansion orientation and place greater emphasis on expenditure quality, spatial targeting, institutional capacity, and policy integration. Education and health expenditures should be designed to generate measurable improvements in learning outcomes, service accessibility, health quality, and welfare gains for poor and vulnerable households. Infrastructure policy should prioritize areas with substantial development deficits, while ensuring that investment is accompanied by maintenance, accessibility, and integration with education, health, and local economic development strategies.

This study has limitations. The relatively short observation period limits the ability to capture the long-term and cumulative effects of public expenditure, particularly in sectors such as education, health, and infrastructure, whose impacts may emerge gradually. In addition, the use of aggregate sectoral expenditure indicators may not fully reflect differences in expenditure composition, program quality, governance effectiveness, and implementation performance across districts. Future research should ex-

tend the temporal scope, disaggregate public expenditure into functional and program-level categories, incorporate governance and institutional quality indicators, and apply dynamic or spatial panel approaches to examine lagged effects, interregional spillovers, and spatially heterogeneous policy impacts.

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