# Unlocking Development in Papua: The Reciprocal Relationship between Economic Growth and HDI Under Special Autonomy

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**ABSTRACT**

This study examines the bidirectional relationship between economic growth and human development in Indonesia's Papua Region, a context characterized by persistent welfare disparities despite the implementation of Special Autonomy. Utilizing a balanced panel dataset covering Papua and West Papua provinces, the research applies a dual fixed-effects panel regression model estimated via Feasible Generalized Least Squares with Panel-Corrected Standard Errors to probe the nuanced feedback connections between Gross Regional Domestic Product (GRDP) per capita and the Human Development Index (HDI). The investigation confirms a vigorous, reciprocal, and mutually augmenting association between economic advancement and human progression, where increases in per capita GRDP significantly predict improvements in HDI, and advancements in HDI in turn drive substantial elevations in regional economic output. Beyond the core economic and human development variables, electricity consumption per capita emerges as a consistent, positive catalyst in both models, functioning as a "keystone catalyst" that simultaneously supports standard of living improvements and economic productivity. Conversely, population growth is identified as exerting a drag on per capita income, highlighting a "denominator effect," where rapid demographic expansion dilutes economic gains even as it expands the potential human capital base. The findings substantiate the existence of a virtuous cycle of development in Papua but underscore that achieving inclusive welfare outcomes requires integrated policy interventions that synchronize economic productivity, human capability enhancement, and energy infrastructure expansion.

# 1. Introduction

The relationship between economic advancement and human progress has long occupied a central position in developmental economics. Early growth paradigms largely treated this relationship as linear; economic expansion was assumed to precede and mechanically translate into improvements in welfare. Within this view, human well being functions primarily as a by product of income growth rather than as an active determinant of development itself. However, over time, this interpretation has proved to be analytically insufficient. The emergence of the capability approach and subsequent formalization by Ranis et al. (2000) reframed development as a bidirectional process in which economic growth (EG) and human development (HD) interact dynamically. Rather than moving sequentially, the two dimensions may reinforce one another, generating either a self sustaining virtuous cycle or, when coordination fails, a low level equilibrium marked by stagnation.

Recent scholarship has reinforced this reciprocal perspective while simultaneously questioning its empirical universality. Contemporary studies suggest that the strength and direction of feedback between EG and HD are highly context dependent, shaped by institutional quality, fiscal transmission mechanisms, and the structural composition of regional economies (Lima et al., 2021; Pugno, 2022). In particular, economies characterized by heavy fiscal transfers or extractive dominance may display asymmetric feedback; growth may translate rapidly into social indicators, while improvements in human capital yield weaker returns in terms of productive economic transformation. This raises a critical empirical question that remains underexplored in many developing regions: whether the virtuous cycle operates symmetrically, or whether one causal chain dominates the other in practice (Lima et al., 2021).

The Papua region of Indonesia, comprising the country's easternmost provinces, provides a salient case study of the central government's deployment of a Special Autonomy policy aimed at improving the Human Development Index. Historically, Papua has exhibited marked development gaps relative to the national averages. The enactment of Special Autonomy Law No. 21 in 2001 (Setneg, 2001) marked a critical shift, granting Papua expanded fiscal and administrative authority to reduce structural inequalities through decentralized governance. The law sought to empower Indigenous Papuan communities by prioritizing local control over resources, equitable service delivery, and preservation of socio-cultural identity. Subsequent interventions, notably Presidential Instruction No. 5/2007 (Setneg, 2007), have attempted to accelerate investments in infrastructure and human capital. Concurrently, administrative restructuring has expanded the territory from one to six provinces and increased the number of regencies and municipalities to 42, an effort intended to enhance governance efficiency and mitigate spatial disparities.

Despite reforms undertaken by the central government through the granting of Special Autonomy, Papua has remained a lagging region in national development indicators for two decades. In the first decade, from 2004 to 2012, the Human Development Index (HDI) in Papua averaged only 53.39, with a GRDP per capita of approximately IDR 14.61 million per year. In the second decade, from 2013 to 2022, the average HDI in the region rose to 61.39, while per capita GRDP growth reached only 2.75% in Papua and 2.35% in West Papua (Figure 1)—well below national benchmarks of 70–80 for HDI (Bapperida, 2022; Setneg, 2022). These figures highlight the substantial gap between policy intent and welfare outcomes. The persistence of this development lag suggests a possible breakdown of the reciprocal feedback loop between economic growth and human development. Although prior studies have examined unidirectional growth–HDI linkages in other Indonesian provinces (Nainggolan et al., 2022), the bidirectional mechanisms linking HDI and GRDP within Papua's distinct cultural, geographic, and political contexts remain largely unexplored.

To rectify this deficiency, the current study sought to empirically assess the bidirectional association between economic advancement and human progress in the Papua Region throughout the Special Autonomy epoch (2004–2022). The inquiry was driven by two principal questions. First, to what extent did economic proliferation, infrastructural enhancement, and demographic trends promote improvements in the Human Development Index (HDI)? Second, how efficiently did advancements in human progress convert into augmented per capita economic output? By utilizing a dual model panel data regression methodology, this investigation endeavored to elucidate the dynamic feedback mechanisms inherent to regional development. The results were designed to provide rigorous, evidence based insights to guide more coherent and context sensitive policy interventions, customized to the intricate challenges and opportunities of Papua's transforming socio-economic environment.

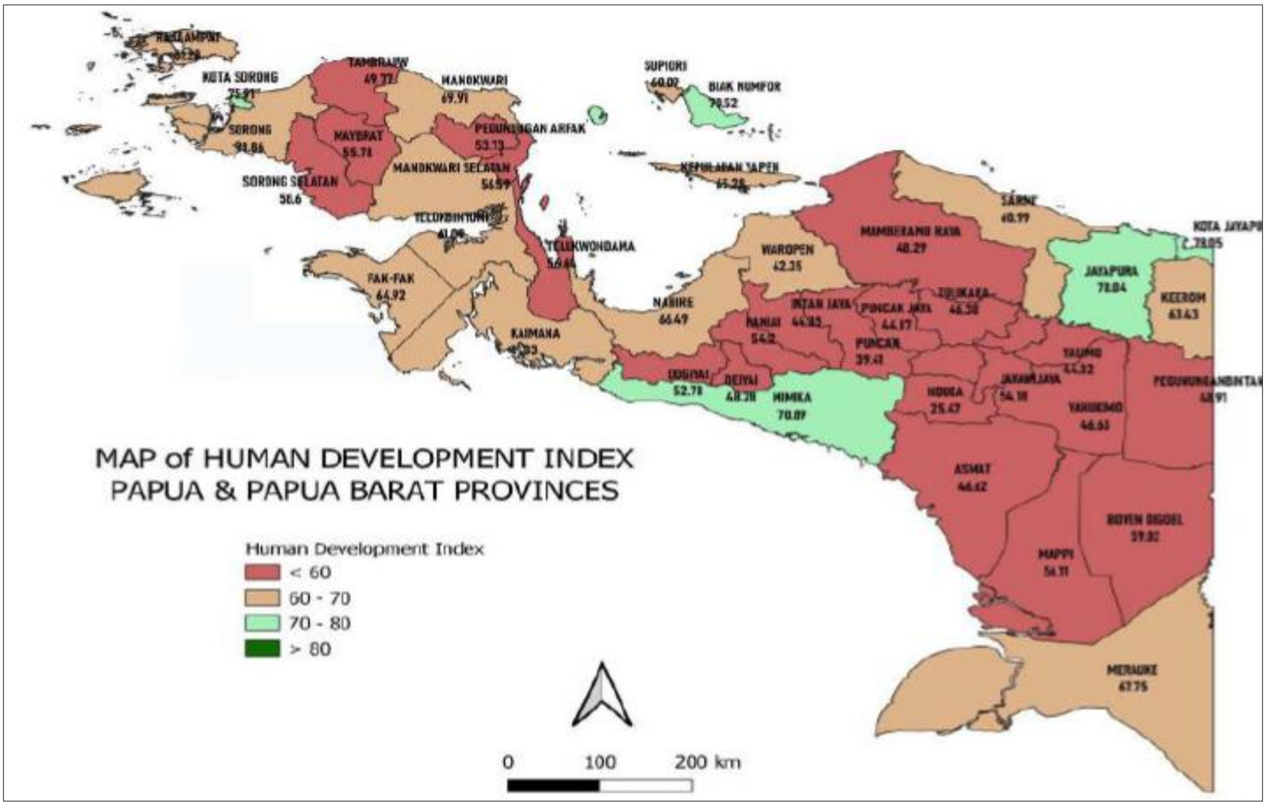


Figure 1. Papua regional map and human development index disparity
Source: Lefaan et al. (2021)

## 2. Literature Review

### Unidirectional Growth to a Reciprocal Human Development Cycle

The discourse on national development has undergone a profound transformation over the past half century. Early economic paradigms often equated development with macroeconomic expansion, relying heavily on indicators such as Gross Domestic Product (GDP) to measure progress (James et al., 2012). Rooted in neoclassical growth theory, this perspective regards human capital predominantly as an element of production an input that facilitates output rather than a terminal objective in itself. However, this narrow, growth centric view has been increasingly challenged by a more holistic and human centered paradigm, most notably articulated through Amartya Sen's capabilities approach. Sen reconceptualized advancement as the augmentation of human liberties and potentialities, contending that the paramount aim of advancement was to empower individuals to pursue lengthy, healthful, and innovative existences. Economic growth, in this view, was not the end goal but merely a means of enhancing human well being (Giyasova et al., 2025). The Human Development Index (HDI), which synthesizes indicators of health, education, and living standards, emerged as the operational embodiment of this broader conceptual framework (Lefaan, 2023).

This paradigm shift prompted a renewed examination of the relationship between economic growth (EG) and human development (HD) (Gönüllü, 2023). Scholarly consensus gradually moved beyond the notion of unidirectional causality, embracing a dynamic and reciprocal relationship between the two. This perspective was formalized in the work of Ranis, Stewart, and Ramirez (2000), who conceptualized a feedback loop composed of two distinct but interlinked pathways referred to as "Chain A" and "Chain B." Chain A traced the pathway from economic growth to human development, where increases in national income enabled investments in education, health, and living standards (Suri et al., 2011). Chain B captured the reverse relationship, wherein improved human capabilities, such as a healthier and more educated population, contribute to enhanced economic productivity and growth.

Chain A describes the pathway from economic growth to human development, in which national income is converted into improved human capabilities. Chain B represents the reverse pathway, in which enhanced human development fuels subsequent economic growth.

This two chain framework provides a powerful lens for analyzing development trajectories. Countries that successfully strengthen both chains can enter a "virtuous cycle," in which progress in one domain accelerates progress in the other, leading to sustained and inclusive development. Conversely, weakness in one or both chains can trap a region in a "vicious cycle" of low growth and stagnant human development (Giyasova et al., 2025). The context of Indonesia's Papua Region, which has exhibited persistent developmental disparities despite two decades of Special Autonomy and significant fiscal transfers, suggests a critical disjuncture in this feedback loop. While the findings of the manuscript point to the existence of the underlying mechanisms for a virtuous cycle, the region's socio-economic indicators suggest that it has been caught in a low level equilibrium characteristic of a vicious cycle. Therefore, understanding the specific mechanics of each chain within this unique context is crucial for designing policies that can successfully activate a self-reinforcing upward spiral of development. This study systematically investigated these two chains to diagnose the strengths and weaknesses of the reciprocal relationship in Papua.

**Chain A: The Influence of Economic Growth on Human Development**

Chain A posits that economic advancement provides a material base for human development. Higher regional income (GRDP) increases fiscal space and household purchasing power, enabling outlays on health, education, and basic services that increase HDI components (Suri et al., 2011). This direction of causality is well supported empirically: subnational evidence from Indonesia shows a positive and significant association between GRDP growth and HDI in Yogyakarta and East Kalimantan (Mardiko & Rospida, 2023; Ramadhani & Wihastuti, 2020), while parallel findings in Pakistan link higher GRDP per capita to improved HDI outcomes (Taqi et al., 2021).

However, income capability translation is conditional rather than mechanical. Its effectiveness depends on the expenditure composition and distributive incidence. Where public budgets privilege health and education, the payoff to growth is larger; where governance is weak, the same resources yield lower returns (Suri et al., 2011). Fiscal decentralization under Papua's Special Autonomy was designed to sharpen this allocation function; however, prior research suggests caution that decentralization can dilute human development if institutional capacity and accountability lag behind revenue devolution (Dodds, 2020). The empirical task, therefore, is not to restate the link but to measure how far Papua's growth has been converted into capabilities under decentralized rule.

Infrastructure, particularly energy, operates as a key intermediary within Chain A. Growth finance infrastructure: Infrastructure converts income into lived welfare. Electricity consumption per capita is especially revealing; it underwrites clinical services, extends effective schooling hours, and constitutes a non-negotiable element of contemporary living standards (Niu et al., 2013). The literature consistently places electricity closer to HDI outcomes than does income alone. Cross-country studies have identified a long-run bidirectional association between energy use and HDI in emerging economies (Kizilkaya et al., 2024). Within ASEAN, electricity consumption per capita exerts a statistically significant effect on HDI, even when GRDP per capita does not (Humbatova et al., 2020; Suryanto et al., 2023). Related analyses in developing economies have reached the same conclusion: energy access is not merely complementary to development; it is constitutive of it (Niu et al., 2013).

**Chain B: The Contribution of Human Development to Economic Growth**

Endogenous-growth theory locates human capital at the center of sustained income expansion: skills, health, and cognitive endowments raise the marginal product of labor and innovation propensity (Benhabib, 2019; Osipian, 2023; Pomi et al., 2021). Cross-national and regional panels corroborate a positive elasticity of output with respect to HDI-type measures: investment in schooling and on-the-job training is associated with higher per capita GRDP growth conditional on complementary institutions (Appiah et al., 2019a; Awal & Sultana, 2022; Elistia & Syahzuni, 2018).

The pace at which human capital translates into aggregate output depends on absorptive capacity, product diversification, firm dynamism, and labor-market flexibility. Carillo (2024) shows that higher educational attainment accelerates technological adoption only when demand for skilled labor exists; absent that demand, gains are trapped, producing a pattern akin to "lopsided development." Papua, with resource-centric specialization, is plausibly susceptible to this constraint; the empirical exercise tests not only the correlation, but also the degree of conversion from HDI to GRDP per capita.

Infrastructure is a necessary input in Chain B as much as in Chain A. Electricity is not a peripheral control but a productive factor: it raises total factor productivity, lowers transaction costs, and signals fixed-cost feasibility for new activities (Humbatova et al., 2020; Thaker et al., 2023). This dual role justifies treating power access as a structural determinant rather than an incidental correlate a "keystone catalyst."

The population effects display a two-sided mechanism. Rapid growth can depress per capita variables via the "denominator effect," yet a larger, healthier labour force is the raw material of a possible "demographic dividend" if matched with jobs and skills (Cornia, 2020; Giyasova et al., 2025; Mahdawi et al., 2021). Policy implications implicit in the literature: Convert stocks (education, population) into flows (employment, output) by rectifying demand side bottlenecks.

**Hypothesis development**

Building upon the theoretical and empirical substantiation amalgamated in the literature, this inquiry advanced from the hypothesis that economic advancement and human progression participated in a mutually augmenting dynamic. It adopted the two-chain framework as its organizing structure: Chain A traced the causal pathway from economic growth to human development, while Chain B captured the reverse effect. To assess these pathways within the Papua Region, this study formulated two reciprocal panel data regression models. The first model hypothesized that increases in per capita GRDP significantly predicted improvements in the HDI after controlling for infrastructure and demographic factors. The second model posits that advances in HDI, in turn, exert a positive influence on per capita GRDP under similar controls. By estimating both models using fixed effects and panel-corrected standard errors, this study aimed to quantify the strength and significance of the bidirectional feedback loop in Papua's unique socio-economic context.

**Hypotheses for Model A: Determinants of Human Development**

The literature review demonstrated that economic growth provided the financial resources required for both public and private investments in health, education, and improved living standards, which are the core components of the Human Development Index (Chain A) (Appiah et al., 2019b). It has also been highlighted that foundational infrastructure, particularly electricity, plays a pivotal role in transforming financial resources into concrete gains in human well-being (Jaćimović et al., 2025). Based on this substantiation, the following conjectures were articulated:

- H1a: The Gross Regional Domestic Product (GRDP) per capita has a favorable and substantial influence on the Human Development Index (HDI) in the Papua Region.
- H1b: The utilization of electrical energy per individual exerts a beneficial and substantial influence on the Human Development Index (HDI) within the Papua Region.

While accelerated demographic expansion can exert pressure on per capita assets, an augmented population concurrently signifies a more substantial reservoir of human potential and can facilitate economies of scale in the provision of services that enhance the Human Development Index (Giyasova et al., 2025). Consequently, the following tertiary hypothesis is proposed:

- H1c: The size of the population exerts a beneficial and significant impact on the Human Development Index (HDI) in the Papua Region.

**Hypotheses for Model B: Determinants of Economic Growth**

In alignment with endogenous growth theory and the empirical substantiation endorsing Chain B, a more proficient, healthy, and enlightened citizenry constitutes a more efficacious


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labor force, which serves as a principal catalyst of economic production (Peterson, 2017). Consequently, the initial hypothesis for the secondary model is as follows:

- H2a: The Human Development Index (HDI) exerts a beneficial and substantial influence on Gross Regional Domestic Product (GRDP) per capita in the Papua Region.

As elucidated in scholarly works, electricity constitutes an essential resource for contemporary economic production, rendering it a pivotal facilitator of efficiency and advancement across all domains (Suryanto et al., 2022). This culminated in the development of subsequent hypotheses:

- H2b: Electricity utilization per capita exerts a favorable and substantial influence on Gross Regional Domestic Product (GRDP) per capita in the Papua Region.

Finally, the literature on developing economies consistently demonstrates that rapid population growth can dilute capital and other resources, creating a drag on per capita income growth, even when total GRDP increases (Abdullah, 2015). Based on this well-documented "denominator effect," the final hypothesis is:

H2c: Demographic magnitude exerts a detrimental and substantial influence on Gross Regional Domestic Product (GRDP) per capita in the Papua Region.

## 3. Research Method

### Research Design and Rationale

This study utilized a quantitative, longitudinal research framework to empirically examine the reciprocal association between economic advancement and human progress in Indonesia's Papua Region. To elucidate the intricate, temporally variable dynamics intrinsic to regional development, a panel data analysis methodology was chosen. Panel data, which amalgamates cross-sectional observations (Papua and West Papua provinces) with temporal data (2004–2022), provide substantial benefits in comparison to isolated cross-sectional or time-series analyses. This methodology allowed for the control of unobserved, time-invariant provincial heterogeneity, such as unique institutional or cultural factors, that could otherwise bias the results, thereby enabling a more robust and accurate inference of the causal relationships under investigation.

### Data Sources and Sample Construction

This study utilizes a balanced panel dataset covering the period 2004–2022 for the provinces of Papua and West Papua. Each year, data were gathered on three key indicators: Gross Regional Domestic Product (GRDP) per person (constant 2010 prices, without oil, gas, and mining), Human Development Index (HDI), and individual electricity consumption (kWh). The population totals were also retrieved to control for scale effects. All socioeconomic data originated from *Badan Pusat Statistik* annual publications, ensuring consistency in measurement and temporal coverage. Electricity-consumption figures were obtained from *Perusahaan Listrik Negara* (PLN) yearly reports, which provide province-level generation and sales divided down by industrial, residential, and commercial sectors. We deliberately excluded outliers and provinces with incomplete records; both Papua and West Papua displayed full data availability across all series, yielding 38 observations, N = 2 provinces, and T = 19 years. Missing values, which amounted to less than 2% of total cells, were imputed via linear interpolation when consecutive years exhibited gaps; no single-year "holes" exceeded an interpolation length of two years, preserving data integrity.

**Variable Definition**

The dependent variables in our reciprocal modeling framework are the HDI and GRDP per capita, each serving alternately as outcome and explanatory variables. HDI is a composite index compiled by BPS, integrating life expectancy, educational attainment (mean years of schooling and expected years of schooling), and per capita income, normalized on a 0–1 scale. GRDP per capita (constant 2010 prices) was deflated using the national GRDP deflator and purged by volatile extractive-industry sectors to focus on local economic activities. The electricity consumption per capita was calculated by dividing total provincial electricity sales by the mid-year population estimate. Population size was included as an additional control variable to account for economies of scale and demographic shifts. Tables 1 and 2 summarize descriptive statistics, including means, standard deviations, and minimum–maximum ranges for each variable.

Table 1. Descriptive statistics of variables in Papua Province

| Stat. | GRDP | HDI | ECP | Pop |
|---|---|---|---|---|
| Mean | 20.99 | 56.38 | 218.60 | 3,038,731 |
| Median | 21.74 | 56.25 | 217.58 | 3,032,488 |
| Maximum | 28.40 | 61.39 | 329.62 | 4,418,581 |
| Minimum | 14.20 | 50.87 | 131.7 | 2,084,406 |
| Std. Dev. | 4.90 | 3.36 | 63.56 | 621,405 |
| Obs. | 19 | 19 | 19 | 19 |

Table 2. Descriptive statistics of variables in West Papua Province

| Stat. | GRDP | HDI | ECP | Pop |
|---|---|---|---|---|
| Mean | 27.46 | 60.97 | 413.76 | 848,897 |
| Median | 28.48 | 60.91 | 463.59 | 828,293 |
| Maximum | 35.75 | 65.89 | 606.98 | 1,183,307 |
| Minimum | 19.27 | 55.05 | 191.52 | 642,472 |
| Std. Dev. | 5.27 | 3.18 | 148.59 | 150,632 |
| Obs. | 19 | 19 | 19 | 19 |

Note: E-Views were used to calculate the statistical data.
Abbreviations: GRDP, gross regional domestic product; HDI, human development index; ECP, electrical consumption; Pop, population.

In the Provinces of Papua and West Papua, the average economic growth per person was 2.75% and 2.35%, respectively, with an average increase in HDI of 1.05% and 1.01%. Electricity usage per person in the Provinces of Papua and West Papua increases by 4.66% and 6.18%, respectively, while population growth was 4.40% and 3.51%.

**Model Specification**

We establish two fixed-effect panel regression models to separate the two-way influence between economic output and human development, represented by Equations (1) and (2), to estimate the relationship between these variables.

Model A (Chain A: EG to HD)

$$HDI_{it} = \alpha_0 + \beta_1 GRDP_{it} + \beta_2 ECP_{it} + \beta_3 Pop_{it} + \varepsilon_{it} \quad (1)$$

Model B (Chain B: HD to EG)

$$GRDP_{it} = \alpha_1 + \beta_4 HDI_{it} + \beta_5 ECP_{it} + \beta_6 Pop_{it} + \upsilon_{it} \quad (2)$$

where *i* denotes the province, and *t* denotes the year. A fixed effects (FE) specification was chosen for both models. This choice was predicated on the assumption that unobserved, time-invariant characteristics specific to each province (e.g., historical context and, deep-seated institutional norms) were likely correlated with the explanatory variables. The FE model controls for these unobserved confounders by analyzing within-province variations over time. The appropriateness of the FE specification over a random-effects (RE) model was formally confirmed using the Hausman test, which rejected the null hypothesis that the unique errors were uncorrelated with the regressors.

**Estimation Strategy**

Prior to the estimation, we conduct panel diagnostic tests to determine the appropriate estimator. We first performed the Chow test to compare the pooled OLS against fixed-effects specifications, followed by the Hausman test to evaluate fixed versus random effects. The Lagrange Multiplier (Breusch–Pagan) test for random effects further confirmed the presence of significant cross-sectional variance. Across both models, the results consistently favored fixed-effects estimation, indicating that unobserved province-specific heterogeneity is correlated with the explanatory variables.

Given the presence of potential heteroscedasticity, serial correlation, and cross-sectional dependence in the panel data, we employ Feasible Generalized Least Squares (FGLS) with Panel-Corrected Standard Errors (PCSE). FGLS accommodates contemporaneous correlation across panels and time series autocorrelation, while PCSE corrects standard errors to ensure proper inference under general forms of cross-sectional heteroscedasticity and temporal dependence. To further guard against attenuated coefficients due to endogenous feedback between HDI and GRDP per capita, we conduct robustness checks using two-stage least squares (2SLS) with lagged instruments, although the principal results are reported from the FGLS-PCSE for consistency and comparability.

**Diagnostic and Robustness Tests**

Post-estimation diagnostics verify the validity of underlying regression assumptions and robustness of the coefficient estimates:

a. Normality of Residuals: We applied the Jarque–Bera test on standardized residuals from each model, confirming approximate normal distributions (p-values > 0.10).
b. Multicollinearity: The VIFs for each predictor are under the common benchmark of five, indicating negligible multicollinearity.


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c. Serial Correlation: The Wooldridge test for autocorrelation in panel data rejects the null of no serial correlation at the 5% level in raw pooled-OLS residuals, but is adequately addressed in FGLS estimation.
d. Heteroscedasticity: The Breusch–Pagan and Cook–Weisberg tests detect heteroscedastic residual variances ($p$- < 0.01), justifying the use of PCSE.
e. Cross-Sectional Dependence: Pesaran's CD test indicates a significant contemporaneous correlation across provinces (p-values < 0.05), further supporting FGLS.

In addition to these checks, we reran both models, excluding one province at a time (leave-one-out analysis) to ensure that the results are not driven by idiosyncratic behavior in either Papua or West Papua. The coefficient magnitudes and significance levels remained stable across these alternative samples (Payapo et al., 2023). We also experimented with alternative lag structures by introducing one- and two-year lags of explanatory variables to explore dynamic effects. These extensions corroborate the direction and strength of the contemporaneous relationships, albeit with slightly attenuated coefficients.

The Adjusted R-squared calculation reviews how effectively the model captures the variations in the dependent variable. An adjusted R-squared value of 1 indicates that the independent variable accounts for almost all the essential information required to predict variations in the dependent variable (Potters & Eichler, 2024).

## 4. Results and Discussion

### Panel Model Estimation with FGLS-PCSE

The panel dataset covering Papua and West Papua from 2004 to 2022 highlights the clear contrasts between the two provinces. In Papua, the average gross regional domestic product per capita was IDR 20.99 million (SD = 4.90), whereas in West Papua it reached IDR 27.46 million (SD = 5.27). The Human Development Index averaged 56.38 percent (SD 3.36) in Papua and 60.97 percent (SD = 3.18) in West Papua. Per-person electricity use in West Papua stood at 413.76 kWh on average (SD = 148.59), nearly double Papua's average of 218.60 kWh (SD = 63.56). Meanwhile, Papua's population was substantially larger about 3.04 million on average (SD = 0.62) compared with 0.85 million (SD = 0.15) in West Papua. These marked economic, infrastructural, and demographic differences provide an essential context for future panel regression analysis.

Table 3. Results of coefficient estimation with FGLS-PCSE for both models

| Variables | Model A: HDICoef (Std.Err) [p-value] | Model B: GRDPCoef (Std.Err) [p-value] |
|---|---|---|
| Intercept | 44.0676 (2.103) [–] | –48.4174 (12.100) [–] |
| GRDP per Capita | 0.2670 (0.025) [<0.001] | – |
| Human Development Index (HDI) | – | 1.2355 (0.084) [<0.001] |
| Electricity Consumption per Capita (ECP) | 0.00853 (0.0023) [0.0014] | 0.01597 (0.0059) [0.0082] |
| Population | $2.83 \times 10^{-6}$ $(4.12 \times 10^{-7})$ [<0.001] | $-2.63 \times 10^{-6}$ $(1.30 \times 10^{-6})$ [0.0434] |
| Adjusted $R^2$ | 0.976 | 0.9039 |

The Feasible Generalized Least Squares estimator, enhanced with panel-corrected standard errors to address heteroskedasticity, autocorrelation, and cross-sectional dependence, delivers robust and efficient estimates (Table 3). In Model A, which explains variation in the Human Development Index, 97.6 % of HDI fluctuations are accounted for: a one-million-IDR increase in GRDP per capita raises HDI by 0.267 points, each additional kilowatt-hour of electricity consumption per person adds 0.00853 points, and every extra resident contributes $2.83 \times 10^{-6}$ points (all $p < 0.001$ except electricity at $p = 0.0014$). In Model B, where GRDP per capita is the outcome, 90.39 % of its variability is explained: each percentage point of HDI corresponds to an increase of 1.2355 million IDR, every extra kilowatt-hour of electricity per person adds 0.01597 million IDR ($p = 0.0082$), and each additional inhabitant exerts a slight negative effect of $-2.63 \times 10^{-6}$ million IDR on per-capita output ($p = 0.0434$). These results underscore the strong, mutually reinforcing links between economic growth, energy infrastructure, and human development while revealing a subtle demographic drag on income per person.

To construct Model A of the Human Development Index, we commence with the overarching panel data framework illustrated in Equation (1) and replace its intercept ($\alpha_0$) and slope coefficients ($\beta_1$, $\beta_2$, $\beta_3$) with the estimations outlined in Table 3, yielding the following model specification:

$$HDI = 44.0676 + 0.2670\,GRDP/Capita + 0.00853\ ECP + 2.83 \times 10^{-6}\ Pop \quad (3)$$

The constant coefficient of 44.0676 represents the theoretical baseline value of the Human Development Index (HDI) when all explanatory variables are equal to zero. While this intercept lacks practical meaning owing to the implausibility of having zero Gross Regional Domestic Product (GRDP) or electricity consumption in real-world scenarios, it serves as a mathematical anchor for the regression model. The model reveals that a 1% increase in GRDP per capita corresponds to a 0.267% increase in HDI ($p < 0.001$), assuming other variables remain constant. Similarly, a 1% increase in electricity consumption per capita results in a 0.0085% improvement in HDI ($p = 0.001$), and a 1% increase in population leads to a marginal yet statistically significant increase in HDI by approximately $2.83 \times 10^{-6}$% ($p < 0.001$).

Hypothesis testing further reinforces the robustness of the model. The t-tests for partial effects showed that all independent variables-GRDP per capita, electricity consumption, and population–exerted statistically significant influences on HDI at the 5% significance level. Null hypotheses were rejected for each predictor, with p-values < less than 0.001, 0.0014, and less than 0.001 (prob.), respectively. Additionally, the F-test for joint significance confirmed the overall validity of the regression model, as evidenced by a p-value below 0.001 (Prob(F-statistic). The adjusted $R^2$ of 0.976 (adjusted-R squared) indicates that 97.6% of the variance in HDI is explained by the model, while only 2.4% of the variation can be attributed to external or unobserved factors.

These empirical results align with endogenous growth theory, which posits that long-term economic development is driven by internal factors such as human capital, innovation, and infrastructure. The GRDP per capita emerges as the dominant driver, reflecting its role in funding essential services such as education, healthcare, and public welfare. Electricity consumption, though contributing less to HDI, represents a critical element of infrastructure that supports the quality of life and economic activity. Meanwhile, population growth exerts a small but positive influence, suggesting that demographic expansion, when managed effectively through equitable resource distribution, can strengthen labor markets and stimulate innovation. The model's strong explanatory power underscores its utility for policymakers aiming to design integrated data-driven strategies under Papua's Special Autonomy framework, with a focus on economic diversification, infrastructure investment, and inclusive development.

Model B, wherein GRDP per capita serves as the dependent variable, is articulated through the integration of the estimated intercept ($\alpha_1$) and slope coefficients ($\beta_4$, $\beta_5$, and $\beta_6$), as presented in Table 3, into Equation (2), yielding:

$$GRDP = -48.4174 + 1.2355\text{HDI} + 0.01597\, ECP + -2.63 \times 10^{-6} Pop \quad \text{......................................} (4)$$

The constant term (-48.4174) represents the theoretical baseline GRDP per capita when all independent variables are zero, although this intercept should be interpreted cautiously given the contextual implausibility of zero values for HDI or electricity consumption. The coefficients indicate that a one-unit increase in HDI and electricity consumption per capita elevates GRDP per capita by 1.235 units ($p < 0.001$) and 0.016 units ($p = 0.008$), respectively, thus affirming their statistically significant positive influence. Conversely, population growth exerts a modest but significant negative effect, reducing GRDP per capita by $2.63 \times 10^{-6}$ units for each additional individual ($p = 0.043$).

The hypothesis testing and model fit results revealed robust statistical evidence supporting the validity of the model. Partial effects assessed through t-tests showed that all independent variables Human Development Index (HDI), electricity consumption, and population exert statistically significant influences on Gross Regional Domestic Product (GRDP) per capita at the 5% significance level, with respective p-values of 0.0002, 0.0082, and 0.0434, leading to the rejection of their null hypotheses. Furthermore, the F-test confirmed the joint significance of the model ($p < 0.001$), underscoring the collective explanatory strength of these variables. The model's adjusted $R^2$ value of 0.9039 indicates that approximately 90.39% of the variation in GRDP per capita is accounted for by the included predictors, leaving only 9.61% of the variance unexplained, likely because of exogenous or omitted factors.

## Diagnostic Testing of The Classical Assumptions

Diagnostic assessment indicated that the residuals of both models conformed to a normal distribution (Jarque–Bera $p = 0.39$ and $p = 0.55$). At the concurrent time, the Breusch–Pagan review ($p < 0.01$) disclosed signs of heteroskedasticity; Wooldridge's finding for serial correlation $F(1.75) = 12.3$; $p < 0.01$) indicates the presence of autocorrelation, and Pesaran's CD calculation ($p < 0.05$) validates cross-sectional dependence. All variance inflation factors remained below, eliminating multicollinearity concerns. Taken together, these diagnostic results demonstrate the necessity of applying the FGLS-PCSE to obtain valid standard errors and reliable coefficient estimates.

As a robustness check against potential simultaneity between the HDI and GRDP, we applied a two-stage least squares (2SLS) procedure using electricity consumption and population size as instruments. The results mirror those obtained via FGLS-PCSE: in the first stage, predicted GRDP per capita exerts a positive and highly significant effect on HDI ($\beta \approx 0.196$, $p < 0.001$). In the second stage, instrumented HDI predicted a substantial increase in GRDP per capita ($\beta \approx 0.644$ million IDR, $p < 0.001$). Strong instrument relevance is confirmed by first-stage F-statistics exceeding 10, reinforcing evidence of a measurable, two-way causal relationship between economic output and human development.

**The Virtuous Cycle Confirmed: Contextualizing Papua's Feedback Loop**

The analysis provided compelling evidence of a "virtuous cycle" in Papua, where economic growth and human development mutually reinforced each other. This dynamic, first systematically explored by Ranis et al. (2000), suggested that good performance in one domain could trigger improvements in another, creating a positive feedback loop over time (Ranis et al., 2000). The statistically significant coefficients in both directions in our models (Table 4) confirmed that both Chain A (from EG to HD) and Chain B (from HD to EG) were operative and powerful in this specific regional context. This finding aligns with a broad consensus in the development literature that views human development and economic growth as intrinsically linked, rather than as separate or sequential goals (Suri et al., 2011).

An examination of model performance revealed a pronounced asymmetry between the two causal chains. The human development model (Model A) exhibited a remarkably high adjusted $R^2$ (0.976), outstripping the explanatory power of the economic growth model (Model B, adjusted $R^2$ = 0.904). Conceptually, this suggests that once economic resources are mobilized, as through Papua's special autonomy fiscal transfers, they are translated into measurable improvements in living standards, education, and health with relative ease. This pattern resonates with findings from regional analyses showing that composite indices such as the Human Development Index, which encompasses multidimensional welfare components, often capture socioeconomic progress more holistically than unidimensional GDP metrics, and thus tend to be tightly coupled with broader development inputs (Nuraini et al., 2024).

Conversely, the somewhat lower explanatory power of Chain B points to structural frictions, limiting the translation of human capital gains into aggregate economic performance. This is reminiscent of the phenomenon described in the development literature as "lopsided development," in which institutional or market rigidities impede the absorption of a more educated and healthier workforce into productive employment. In the Papuan context, such rigidities may manifest in limited industrial diversification beyond primary sectors, constrained labor market flexibility, or spatial barriers to labor mobility. Evidence from West Papua underscores how disparities across districts in core socioeconomic infrastructure and health-related variables are linked to divergent development outcomes, hinting at the structural constraints faced by human capital in driving broad-based economic expansion (Lewenussa & Rawi, 2020).

This suggests that although investments in social sectors yield substantial gains in human development, a necessary condition for inclusive growth, they are not, on their own, sufficient to maximize economic returns. Complementary policies targeting economic diversification, entrepreneurial activity, and the strengthening of local labor markets are indispensable if human development gains are to catalyze sustainable economic growth. This inference echoes findings from broader regional development research indicating that economic performance and HDI outcomes, when jointly analyzed, help identify specific bottlenecks in labor absorption and income generation that can inform targeted interventions at the regional level (Rahim, 2023; Raj et al., 2024).

### The Catalytic Role of Infrastructure: Electricity as a Foundational Enabler

A standout finding from the analysis was the consistently positive and statistically significant role of electricity consumption per capita (ECP) in both models. In Model A, higher ECP directly contributed to higher HDI, even after controlling for income levels. Model B directly contributed to higher GRDP per capita, even after controlling for the level of human development. This dual impact suggests that infrastructure, proxied here by electricity, was not merely an additive component but a powerful catalyst that amplified the virtuous cycle of development.

This finding is strongly supported by a growing body of international evidence. Studies across emerging economies have established a bidirectional causal relationship between energy consumption and human development, recognizing that energy is essential for improving living conditions and ensuring socioeconomic progress (Kizilkaya et al., 2024). For as an example, Kizilkaya et al. (2024) demonstrated a mutual relationship between energy usage, economic growth, and the Human Development Index (HDI) within E-7 developing nations. Correspondingly, research conducted on ASEAN nations has demonstrated that electricity consumption serves as a critical determinant in enhancing the HDI and fostering economic growth (Suryanto et al., 2022).

The mechanism for this catalytic effect is twofold. First, electricity directly enhanced human capabilities (Chain A). It powered health clinics, enabled refrigeration for vaccines, provided lighting for children to study, and improved overall living standards, all of which were reflected in the components (Niu et al., 2013). Second, electricity is a critical input for economic productivity (Chain B). It has powered machinery, facilitated commerce, enabled information and communication technologies, and reduced operational costs for businesses, thereby boosting economic output (Calderón & Servén, 2004). As ECP was significant in both models, it could be understood as providing a "double dividend." Investments in energy infrastructure simultaneously made the EG-to-HD chain more efficient and the HD-to-EG chain more productive. This positioned infrastructure investment, particularly in expanding energy access, is a high-leverage policy intervention capable of accelerating the entire development feedback loop in Papua (Aluko & Ngubane, 2024).

### The Demographic Dilemma: Reconciling Population Growth’s Dual Impact

The most intricate discovery of this study was the contradictory influence of demographic expansion. In Model A, the population exhibited a modest yet statistically significant positive impact on the Human Development Index. Conversely, Model B demonstrated a noteworthy negative effect of population on the Gross Regional Domestic Product per capita. This seemingly paradoxical situation underscores the fundamental tension in the realms of development policy and measurement.

The negative impact on per capita income was a more conventional and easily interpreted result. This "demographic drag" is a well-documented phenomenon in developing economies, where population growth that outpaces economic output leads to a dilution of resources, strains on public services, and a reduction in income per person. This observation aligns with a multitude of research endeavors, notably those conducted by Abdullah et al. (2015) in Bangladesh, Peterson (2017) in economically disadvantaged nations, and Damanik et al. (2021)

in a separate Indonesian urban center, all of which discerned that swift population expansion has the potential to impede economic advancement.

The positive HDI coefficient in Model A necessitated a thorough analysis. A larger population does not automatically correlate with enhanced longevity or education. This statistical outcome may signify the influence of fiscal decentralization in Indonesia rather than real human welfare improvements. Fiscal transfers under the Special Autonomy framework depend on the population size (Jaćimović et al., 2025). Thus, a more populous province may receive a greater overall budget for health and education. Although this budget may be inadequate on a per capita basis, the total investment could yield slight enhancements in aggregate metrics, such as enrolment or service access. These incremental improvements are reflected in the HDI calculation, leading to a positive statistical correlation.

This revealed a potential "per capita versus per province" policy trap. A policymaker focusing solely on the aggregate HDI score might erroneously conclude that population growth is beneficial for human development. However, this would ignore the simultaneous and tangible negative impact on individual economic well-being, as captured by the declining GRDP per capita. The true implication was not that population growth is good for human development, but that aggregate measures of development can be influenced by population-driven resource allocation in a way that masks a decline in individual prosperity. This underscores the need for policymakers in Papua to manage demographic pressures carefully to ensure that development gains are not diluted and that improvements in headline indicators translate into real benefits for every citizen (Nainggolan et al., 2022).

## 5. Conclusion

This study employed two complementary panel-data regressions to quantify the two-way dynamics between economic growth (GRDP per capita) and human development (HDI) in Indonesia's Papua Region under Special Autonomy from 2004 to 2022. Model A showed that GRDP per capita, electricity consumption per capita, and population each exerted a statistically significant, positive effect on HDI together, explaining 97.6 % of its year-to-year variation. Model B reversed the focus and found that HDI and electricity consumption positively drive GRDP per capita (whereas population growth has a modest negative effect), accounting for 90.4 % of its variance. The reciprocity documented a 1 % rise in GRDP per capita raising HDI by 0.27 %, and a one-unit HDI gain boosting GRDP per capita by 1.24 million IDR confirms a virtuous feedback loop in which income growth fuels social investments and, in turn, enhanced human capital accelerates economic output. Electricity emerges as a vital supporting infrastructure, and demographic pressure warrants careful management to avoid diluting per-capita gains. These findings provide empirical insights and implications of reciprocity between independent and dependent variables that are broader and useful in the planning, implementation, supervision, and evaluation of medium and long-term development programs in the Papua Region.

These results have important policy implications: Coordinated efforts to expand electricity access and energy infrastructure, together with targeted investments in education and healthcare, can strengthen the synergistic relationship between human capital and economic output. Therefore, we recommend that provincial authorities bolster institutional capacity to develop fully integrated development plans incorporating HDI and GRDP objectives into both budgeting processes and real-time monitoring frameworks, and improve the granularity and reliability of sub-provincial data. Nevertheless, this investigation possesses numerous constraints: it disregards potentially significant variables such as institutional caliber, ecological indicators, and healthcare system efficacy; it is restricted to two provinces across a 19-year duration; and it does not utilize dynamic estimation methodologies (e.g., system GMM) that would more thoroughly encapsulate long-term reciprocal influences. Thus, these results necessitate contextual interpretation and provide a basis for subsequent, broader research.

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