

A Spatial Approach: The Impact of Information and Communication Technology (ICT) Development on Reducing Educational Inequality in Papua, 2024

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Abstract

Education is a national development priority that is a strategic element in promoting the adoption of modern technology and sustainable growth, as reflected in National Long-Term Development Plan (RPJPN) 2025–2045 and the fourth Sustainable Development Goal (SDG). However, educational inequality in Papua and West Papua remains a serious challenge in terms of equitable access to quality education. This study aims to evaluate the impact of digital development on educational inequality in these two provinces. Secondary data from the Central Statistics Agency (BPS-Statistics) and the Directorate General of Fiscal Balance (DJPK) were analyzed using the Spatial Error Model (SEM) to examine the influence of Information and Communication Technology (ICT) on the Education Gini Coefficient (EGC). The results show that variables such as internet access for people aged 7-18 years, the Community Literacy Development Index (IPLM), Mean Years of School (MYS), and regional education budgets play a significant role in reducing educational inequality. These findings confirm that digital development plays a strategic role in creating an inclusive and equitable education system. This research is expected to serve as a basis for formulating adaptive technology-based education policies to overcome educational inequality in Papua Island.

Keywords: *Educational Inequality, Spatial Regression, ICT*

1. INTRODUCTION

Education is a fundamental right guaranteed by the Constitution and constitutes a national development priority in Indonesia, as stipulated in constitution (Undang-Undang

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Dasar 1945 Pasal 31) and Rencana Pembangunan Jangka Panjang Nasional (RPJPN) 2025–2045, which aims to ensure the provision of equitable and high-quality education. The global commitment to educational equity is also reflected in the fourth goal of the Sustainable Development Goals (SDGs), which emphasizes the importance of inclusive, equitable, and quality education and the promotion of lifelong learning opportunities for all (Hák et al., 2016). Nevertheless, educational inequality remains highly pronounced in the Papua region, as evidenced by substantial disparities in access to education, educational quality, and learning outcomes across regencies and municipalities.

Data from the Higher Education Service Institution (LLDikti) Region XIV indicate that the Gross Enrollment Ratio (GER) in higher education in Papua is only 11 percent, substantially below the national average of 35 percent (Kemendiktisaintek, 2025). Several regencies, including Jayawijaya, Paniai, and Pegunungan Bintang, record an mean years of school of less than six years, whereas Jayapura City and Nabire have attained secondary education levels menengah (Afriansyah, 2023; Purwantono & Faridatussalam, 2024). These disparities are further exacerbated by challenging geographical conditions, limited basic infrastructure, and the uneven distribution of teaching personnel (Lewaherilla, 2025).

Educational inequality has far-reaching social and economic consequences. Children from low-income households who lack access to education are more likely to be trapped in cycles of poverty and are increasingly vulnerable to criminal behavior (Legewie & Fagan, 2019; Madriz, 2023). From an economic perspective, educational disparities widen income gaps between groups with access to high-quality education and those who are systemically marginalized (Lee & Lee, 2018; Coady & Dizioli, 2018). In the long run, such inequalities hinder social mobility and weaken regional competitiveness. These disparities not only reflect limited physical access to educational services but also indicate the uneven spatial distribution of educational resources.

Within the context of digital transformation, Information and Communication Technology (ICT) has been widely recognized as a catalyst for expanding educational access and enhancing learning efficiency, particularly in regions facing physical and geographical constraints (Bejinaru, 2019). ICT facilitates distance learning, curriculum digitalization, and the use of spatial data for more adaptive educational planning. However, the effectiveness of ICT-based interventions is highly dependent on the readiness of digital infrastructure and the level of technological literacy within communities. In Papua, the utilization of ICT remains suboptimal, as low digital literacy, limited technological infrastructure, and the population's constrained economic capacity constitute major barriers to the integration of ICT into the education system (Albion and Tondeur 2018; Lewaherilla, 2025).

In Papua, these challenges remain highly pronounced. According to data from APJII, internet penetration in Papua reached only 63.15% in 2023, declining from 68.03% in the previous year, and remains among the lowest levels nationally (Asosiasi Penyelenggara Jasa Internet, 2024). The digital literacy score in Central Papua stands at 17.8 points, far below the national average of 35.2 points. In addition, only 18.52% of households in Papua own a computer, and the majority of schools in remote areas are not yet connected to stable internet networks (Lewaherilla, 2025). This low level of ICT penetration indicates that the potential of technology as an instrument for promoting educational equity has not been optimally harnessed and may, in fact, exacerbate existing inequalities rather than alleviate them.

A growing body of literature has examined educational inequality from social, economic, and fiscal policy perspectives (Banzragch et al., 2019; Hendajany et al., 2022; Setyadi, 2022). However, these studies predominantly rely on conventional analytical approaches that do not adequately incorporate spatial dimensions. As a result, their findings tend to be aggregate in nature and are limited in their ability to capture geographical interdependencies across regions. To date, no study has explicitly analyzed the impact of digital development on educational inequality in Papua using a spatial approach. Such an approach is crucial, as it enables the identification of the geographic distribution of educational disparities and facilitates a more precise delineation of priority areas for technological intervention (Anselin, 1988; Zheng & Graham, 2022).

Based on this background, the present study aims to: (i) provide an overview of educational inequality on the island of Papua in 2024, and (ii) analyze the effects of variables related to digital development on educational inequality in the Papua region using inferential analysis with a spatial analytical approach for the year 2024. The findings of this study are expected to offer empirical contributions to the formulation of technology-based education policies that are inclusive, adaptive, and equitable in the Papua region.

2. LITERATURE REVIEW

2.1. Educational inequality

Educational attainment inequality refers to a condition in which the distribution of educational outcomes is uneven. Educational inequality reflects disparities in educational outcomes across regions, indicating differences in achievement between one area and another. Such inequality can be measured using the Education Gini Coefficient (EGC), calculated using the following formula (Yuniar & Yuniasih, 2022):

$$E_L = \frac{1}{\mu} \sum_{i=2}^6 \sum_{j=1}^{i-1} p_i |y_i - y_j| p_j \quad (1)$$

Notes:

E_L : Education Gini Coefficient

μ : Average years of schooling

p_i and p_j : proportions of the population with a given level of completed education, $i \neq j$

y_i and y_j : years of schooling corresponding to the completed level of education, $i \neq j$

The categories of the highest level of educational attainment completed include: (1) 0 years for individuals who have never attended school, (2) 3 years for those who did not complete primary school, (3) 6 years for primary school graduates, (4) 9 years for junior secondary school graduates, (5) 12 years for senior secondary school graduates, and (6) 15 years for university graduates. The EGC ranges from 0 to 1. Values closer to 0 indicate a more equal distribution of educational attainment, whereas values approaching 1 signify an increasingly unequal or skewed distribution.

In this study, the classification of EGC values follows the categories proposed by (Rahayu, 2005) as cited in (Yuniar & Yuniasih, 2022), namely: very low inequality for EGC values below 0.2; low inequality for values between 0.2 and 0.35; moderate

inequality for values ranging from 0.36 to 0.49; high inequality for values between 0.5 and 0.7; and very high inequality when the EGC exceeds 0.7. High levels of educational inequality, particularly in underdeveloped regions such as Papua, are not only spatial in nature but also multidimensional, thereby necessitating adaptive and context-specific intervention approaches.

One strategic approach that is highly relevant in this context is the development of ICT, which has been shown to expand access to learning, support curriculum digitalization, and enhance the efficiency of teaching and learning processes, particularly in regions with physical and infrastructural constraints (Bejinaru, 2019). Digital literacy, as an integral component of ICT development, reflects individuals' capacity to access, comprehend, and productively utilize information technology within educational contexts (Albion and Tondeur 2018). Accordingly, digital development in Papua plays a crucial role in bridging educational gaps through online learning and data-driven education management, while also serving as a foundation for sustainable educational equity.

To empirically measure digital development, this study employs six key indicators that have been validated in previous research. First, the percentage of the population aged 7–18 years who access the internet is used to assess the level of young people's access to digital learning resources and the potential for innovation in learning methods (Zheng and Graham 2022). Second, the percentage of households owning a computer reflects the availability of technological devices that support the implementation of online and blended learning. Third, the Community Literacy Development Index (IPLM) is utilized to evaluate the capacity of communities to optimally use information and technological resources within blended learning processes (Albion and Tondeur 2018; Fernback 2018).

Fourth, mean years of schoolis employed as an indicator of the level of formal education attained by the population in a given region, as longer educational duration can reduce disparities across social groups (Adiningtyas & Budyanra, 2020). Fifth, regional education expenditure represents the fiscal capacity of local governments to provide equitable and high-quality educational services (Setyadi 2022). Sixth, Gross Domestic Regional Product (GDRP) per capita and household expenditure on internet access are used as indicators of digital economic capacity that enables the sustainable utilization of educational technologies (Spivakovsky et al. 2020).

Papua's vast and mountainous geography, combined with limited transportation networks, makes access to educational facilities in remote areas extremely challenging, resulting in substantial variation in the quality of education and learning opportunities available to local communities. Educational inequality can be examined through a spatial perspective by referring to Tobler's law, which states that "everything is related to everything else, but near things are more related than distant things" (Anselin, 1988).. In the Papuan context, geographically distant areas tend to exhibit weaker social and economic linkages, thereby intensifying disparities in educational access and quality between core regions and remote areas. Accordingly, this study adopts a spatial analytical approach to identify patterns of educational inequality and to assess the geographically differentiated effects of digital development.

2.2. Data and Data Resource

The data employed in this study consist of primary and secondary data. Primary data are derived from the raw microdata of the National Socio-Economic Survey

(SUSENAS), officially published by BPS-Statistics, as well as data from the Directorate General of Fiscal Balance (DJPK). These primary data are used to calculate EGC.

Secondary data are obtained from official statistical publications issued by BPS-Statistics, including the percentage of the population aged 7–18 years who access the internet, the percentage of households owning a computer, and the percentage of the population aged 7–18 years who use mobile phones or smartphones. The dataset constitutes panel data with 42 regencies/municipalities on the island of Papua as the units of observation for the year 2024, with the variables detailed in Table 1.

Table 1. Details of research variables

Variable	Simbol	Unit	Source
Dependent Variable			
Education Gini Coefficient (EGC)	EGC	Point	BPS-Statistics
Independent Variable			
Percentage of population aged 7-18 years who access the internet	X_1	Percent	BPS-Statistics
Percentage of households that own a computer	X_2	Percent	BPS-Statistics
Community Literacy Development Index (IPLM)	X_3	Index	BPS-Statistics
GRDP per capita / population expenditure on internet	X_4	Billion Rupiah	BPS-Statistics
Mean Years of School (MYS),	X_5	Year	BPS-Statistics
Regional Education Budget	X_6	Billion Rupiah	DJPK

2.2. Data and Data Resource

Spatial regression represents an extension of conventional linear regression by explicitly incorporating spatial or geographical dimensions. This approach accounts for spatial dependence across observational units. Three primary spatial regression models are commonly applied within the spatial dependency framework: the Spatial Autoregressive (SAR) model, the Spatial Error Model (SEM), and the Spatial Autoregressive Moving Average (SARMA) model (Ge et al., 2018). The SAR model accounts for spatial dependence that arises directly in the dependent variable, while the SEM model captures spatial dependence through the error term, reflecting correlations among unobserved factors across regions as well as their association with local characteristics. The SARMA model integrates features of both SAR and SEM. The mathematical specifications of multiple linear regression and spatial regression models are presented in Table 2 (Anselin & Li, 2020; Elhorst, 2014; Ward, M. D., & Gleditsch, 2018).

Table 2. Details of research models

Model	Equation
Spatial Lag Model (SLM)	$y = \beta_0 + \rho W y + \sum_{i=1}^n \beta_i X_i + \varepsilon_i$
Spatial Error Model (SEM)	$y = \beta_0 + \sum_{i=1}^n \beta_i X_i + \mu \text{ with } \mu = \lambda W + \varepsilon_i$
Spatial Autoregressive Moving Average (SARMA) Model	$y = \beta_0 + \rho W y + \sum_{i=1}^n \beta_i X_i + \mu \text{ with } \mu = \lambda W + \varepsilon_i$

Details:

β_0	= constant	w	= weight
β_i	= regression coefficient of variable i	ρ	= spatial lag coefficient
y	= dependent variable	λ	= spatial error coefficient
x_i	= independent variable i	ε_i	= error

3. METHODS

The following steps were undertaken to conduct the spatial analysis in this study:

1. Estimating a multiple linear regression model using the Ordinary Least Squares (OLS) estimation method.
2. Identifying spatial effects to determine whether spatial autocorrelation is present in the data. This step employs Moran's I test using a Queen contiguity spatial weight matrix, which assumes that locations sharing either a common boundary or a common vertex are considered neighbors.
3. Testing for spatial dependence using Lagrange Multiplier (LM) statistics (LM-lag and LM-error). If the LM-lag test is significant, the appropriate model is the Spatial Lag Model (SLM) or Spatial Autoregressive Model (SAR). If the LM-error test is significant, the appropriate model is the Spatial Error Model (SEM). If neither test is significant, Robust Lagrange Multiplier (RLM-lag and RLM-error) tests are conducted. If the RLM-lag test is significant while the RLM-error test is not, the appropriate model is the Spatial Lag Model (SLM) or Spatial Autoregressive Model (SAR). Conversely, if the RLM-error test is significant while the RLM-lag test is not, the Spatial Error Model (SEM) is selected. If both LM and RLM tests for lag and error are significant, the appropriate model is the Spatial Autoregressive Moving Average (SARMA) model.
4. Specifying the appropriate spatial regression equation based on the selected model.
5. Conducting partial significance tests for the estimated parameters.

4. RESULTS

4.1 Overview of the Education Gini Coefficient (EGC) on the Island of Papua in 2024

Based on Figure 1, several regencies in Papua namely Jayawijaya, Paniai, Puncak Jaya, Asmat, Yahukimo, Pegunungan Bintang, Tolikara, Nduga, Lanny Jaya, Mamberamo Tengah, Yalimo, Puncak, Dogiyai, Intan Jaya, and Deiyai consistently exhibit higher levels of educational inequality than the provincial average for Papua over time. This pattern is consistent with findings indicating that these regencies have low average years of schooling, which contributes to elevated levels of educational inequality. Overall, the majority of regencies/municipalities in Papua continue to record low educational attainment. This is evidenced by the fact that more than half (15 out of 29) of the regencies/municipalities in Papua had mean years of school that remained well below the basic education benchmark of six years as of 2024. These include Jayawijaya (5.98), Paniai (4.79), Puncak Jaya (4.23), Asmat (5.58), Yahukimo (4.34), Pegunungan Bintang (3.37), Tolikara (3.68), Nduga (1.71), Lanny Jaya (3.71), Mamberamo Tengah (3.63), Yalimo (3.34), Puncak (2.19), Dogiyai (4.97), Intan Jaya (3.27), and Deiyai (3.27). This situation is particularly concerning given that regencies/municipalities in other provinces have generally achieved mean years of school exceeding six years. In contrast, Jayapura Regency (10.32), Nabire (10.33), Biak Numfor (10.54), Mimika (10.47), and Jayapura City (11.84) have attained mean years of school corresponding to upper secondary education. The stark variation in mean years of school across regencies in Papua clearly illustrates the presence of substantial educational inequality within the region.

West Papua exhibits a different pattern. Educational attainment inequality across regencies/municipalities in West Papua is generally lower than that observed across regencies/municipalities in Papua. Nevertheless, most regencies/municipalities in West Papua display levels of educational attainment inequality that are higher than the provincial average. The majority of regencies/municipalities in West Papua have achieved mean years of school exceeding six years; however, two of the thirteen regencies are Tambrauw (5.71) and Pegunungan Arfak (5.51) still record mean years of school below the six-year threshold. The persistence of these low schooling levels in certain areas indicates the continued presence of educational attainment disparities across regencies/municipalities in West Papua. Meanwhile, Sorong City is the only area in West Papua where educational attainment inequality is consistently lower than the provincial level, and in 2024, Fakfak Regency also recorded educational attainment inequality below the West Papua provincial average.

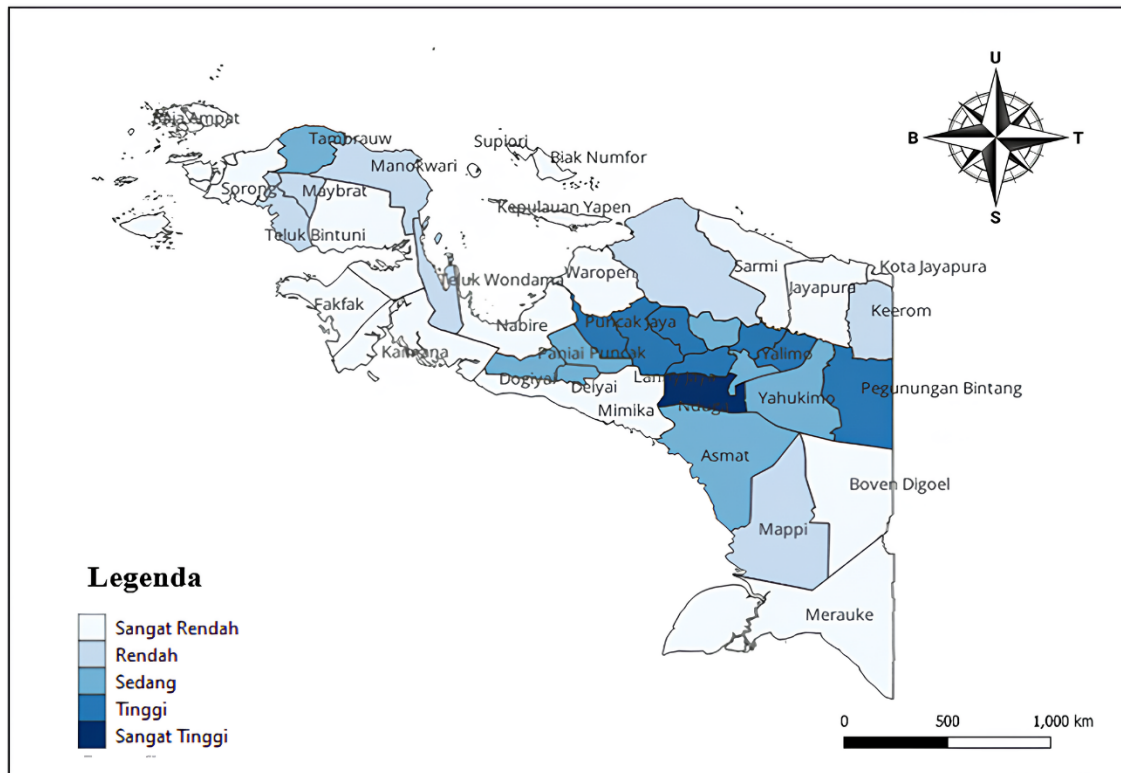


Figure 1. Education Gini Coefficient (EGC) on the Island of Papua in 2024

4.2 The Impact of Information and Communication Technology (ICT) on Educational Inequality on the Island of Papua in 2024

At the initial stage of spatial modeling, a multiple linear regression was estimated using the OLS method. The F-statistic results indicate a p-value of less than 5 percent, leading to the rejection of the null hypothesis (H_0). This implies that the independent variables, when considered jointly, have a statistically significant effect on the EGC in Papua in 2024. Subsequently, Moran's I statistic was computed using a queen contiguity spatial weight matrix. The resulting Moran's I value of 0.178 indicates the presence of positive spatial autocorrelation. This finding suggests that educational inequality in Papua exhibits a non-random spatial pattern and is spatially interrelated across regions.

Table 3. LM-Test for selecting the best model

Variabel	MI/DF	Nilai Statistik	<i>p-value</i>
<i>LM-lag</i>	1	2.524	0.074
<i>LM-Error</i>	1	9.273	0.002*

* Significant at 5% alpha

Source: Processing results

After identifying the presence of spatial autocorrelation, LM tests were conducted to determine whether spatial dependence arises from the lag or the error component. Table 3 shows that the p-value of the LM-lag test is 0.074, which exceeds the 5 percent significance level and is therefore not statistically significant. In contrast, the p-value of the LM-error test is 0.002, which is below the 5 percent significance threshold, leading to the rejection of H_0 . Accordingly, the SEM is identified as the most appropriate model for this study.

Table 4. Spatial Regression Estimation Results – SEM

Variable	Coefficient	Standar error	p-value
<i>Intercept</i>	0,195	2,619	0,000*
X_1	-0,024	0,022	0,027*
X_2	0,034	1,921	0,233
X_3	-0,045	0,022	0,000*
X_4	0,001	1,921	0,067
X_5	-0,025	0,230	0,002*
X_6	-0,003	1,708	0,035*
λ	-0,002	0,098	0,000*

* Significant at 5% alpha

Source: Processing results

Subsequently, the SEM was specified, and parameter estimation was performed as presented in Table 4. The SEM regression results can be expressed in Equation (1), which is formulated as follows:

$$EGC = 0,195 - 0,024X_1^* + 0,034X_2 - 0,045X_3^* + 0,001X_4 - 0,025X_5^* - 0,003X_6^* - 0,002 \sum_{i=1}^n \widehat{w}_{ij} \varepsilon_{ij}^* \quad (2)$$

This study demonstrates that digital development makes a significant contribution to reducing the level of educational inequality in Papua. The technological variables analyzed namely the percentage of the population aged 7–18 years who access the internet (X_1) and the IPLM (X_3) exhibit a negative and statistically significant relationship with the EGC (Y). These findings indicate that digital development is not merely a complementary component of the education system, but rather a strategic determinant in promoting equitable access to and quality of education.

More specifically, a one-percentage-point increase in internet access among the population aged 7–18 years is associated with a reduction in educational inequality of 0.024 points, *ceteris paribus*. Broader internet access enriches students' learning experiences by providing more diverse educational resources and enabling access to information that was previously difficult to obtain. Particularly in areas with limited educational infrastructure, the internet can serve as an effective tool for equalizing educational opportunities regardless of geographical location or facility constraints. Through greater access to online learning resources such as educational videos, tutorials, and distance learning platforms students from diverse backgrounds can enhance their

skills and knowledge, thereby contributing to a reduction in educational disparities within society.

The observed decline in the EGC alongside increased internet access suggests that digital technology plays a critical role in promoting educational equity. These findings underscore the importance of expanding access to technology and internet connectivity to support more inclusive and equitable educational outcomes and to reduce inequality in the education sector. The results of this study are consistent with previous research (Billon et al., 2018; Favara et al., 2022; Korkmaz et al., 2022; Rahma & Kartiasih, 2024).

Furthermore, the IPLM variable exhibits the strongest effect, with a coefficient of -0.045 . This implies that a one-point increase in the IPLM leads to a 0.045-point reduction in educational inequality, *ceteris paribus*. Improvements in community literacy reflect enhanced individual capacity to understand, evaluate, and critically utilize information, which in turn strengthens participation in educational processes. Communities with higher literacy levels tend to better recognize the importance of education and are more actively involved in supporting children's educational development, both at home and in school. Moreover, increased literacy encourages greater engagement in lifelong learning, thereby narrowing the gap between those with adequate educational access and those who are systematically disadvantaged.

The reduction in the Education Gini Coefficient associated with higher IPLM values highlights the crucial role of literacy development in fostering a more educated society and mitigating educational inequality. These findings emphasize the importance of investing in literacy programs to strengthen the educational foundation and promote more equitable education across all segments of society. This result is in line with the findings of Tchamyou (2020).

Consistent with these results, MYS (X_5) also shows a significant negative relationship with the EGC (Y). An increase of one year in the mean years of school in a region reduces educational inequality by 0.025 points, *ceteris paribus*. Longer educational duration plays a vital role in expanding access to and improving the quality of education across all social groups, thereby reducing inequality in educational attainment. Extended schooling enables broader and more equitable participation in education and helps narrow gaps between social groups, particularly those that previously had limited access. These findings suggest that investment in improving educational quality and extending schooling duration constitutes an effective strategy for reducing social inequality, especially in the education sector, and are consistent with the findings of Khusaini et al. (2020).

Beyond educational duration, fiscal support through the allocation of School Operational Assistance (BOS) funds (X_6) is also shown to have a significant effect in reducing educational inequality. The results indicate that an increase of IDR 1 billion in BOS funding allocated to schools contributes to a 0.003-point reduction in educational inequality, *ceteris paribus*. Through BOS funding, schools across regions can enhance service quality, improve facilities, and provide better educational resources, particularly in disadvantaged areas. These findings reinforce the importance of regional education budgets in supporting educational equity and reducing disparities, especially through targeted funding allocations to schools in need. Accordingly, greater investment in programs such as BOS represents a strategic step toward achieving a more inclusive and

equitable education system. These results are consistent with previous studies by Setyadi (2022) dan Yuniar and Yuniasih (2022) .

To further strengthen the spatial analysis, this study also identifies the presence of spatial dependence effects, represented by the lambda (λ) parameter. This value captures changes in the EGC resulting from changes in variables in neighboring regencies/municipalities. Based on the SEM regression results for regencies/municipalities on the island of Papua, the lambda coefficient indicates negative spatial error dependence, with a value of 0.002. This suggests that changes in unobserved factors in surrounding provinces also influence educational inequality within regencies/municipalities in Papua. These findings reinforce the relevance of a spatial approach in analyzing educational inequality and highlight the importance of policy interventions that explicitly consider interregional dynamics.

5. CONCLUSION

This study finds that educational attainment inequality across regencies/municipalities in Papua Province tends to be greater than that observed among regencies/municipalities in West Papua Province. Nduga Regency exhibits the lowest level of educational attainment inequality on the island of Papua, whereas Jayapura records the lowest educational inequality overall on the island. These findings underscore the presence of spatial disparities in the distribution of education in eastern Indonesia.

Digital development is empirically shown to be a strategic factor in reducing educational inequality and promoting a more even distribution of educational quality in Papua. Based on Structural Equation Modeling (SEM) results, the percentage of the population aged 7–18 years accessing the internet, IPLM, MYS, and regional education expenditure all have significant effects in reducing educational disparities across regencies/municipalities on the island of Papua. Among these variables, the IPLM demonstrates the most dominant influence in lowering educational inequality, indicating that community literacy is a key determinant in achieving educational equity. Accordingly, local governments should prioritize strengthening community literacy through improved access to learning resources, the development of libraries, and the implementation of community-based literacy programs tailored to local conditions as a strategy for achieving sustainable educational equity in Papua.

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