Asian Journal of Economic Modelling
ISSN(e): 2312-3656
ISSN(p): 2313-2884
DOI: 10.55493/5009.v13i3.5577
Vol. 13, No. 3, 419-436.

URL: www.aessweb.com

Poverty reduction and digitalization in Indonesia: The conditional role of human capital and economic growth in an underdeveloped province

Rully Novie Wurarah[1+]
Maryam Sangadji[2]
Sarce Babra Awom[3]

[1,3]*Papua University, Faculty of Economics and Business, Department of Economics, Indonesia.*
[1]*Email: r.wurarah@unipa.ac.id*
[3]*Email: s.awom@unipa.ac.id*
[2]*Pattimura University, Faculty of Economics and Business, Department of Economics, Indonesia.*
[2]*Email: maryam_sng@yahoo.co.id*

(+ Corresponding author)

Article History
Received: 1 June 2025
Revised: 22 July 2025
Accepted: 15 August 2025
Published: 12 September 2025

Keywords
Digital divide
E-commerce
Human capital
Inclusive growth
Indonesia
Spatial econometrics.

JEL Classification:
O15; I32; O33; R11; C23; R12.

ABSTRACT

The purpose of this study is to explore how human capital could help close the digital divide in Indonesian areas currently under development. Digitalization is proxied by MSMEs actively using e-commerce platforms (≥ transactions/month), sourced from the Ministry of Communication and Informatics. Using panel data from the 10 provinces with the lowest human development index (HDI) in Indonesia from 2019 to 2023, we contrast the efficiency of digitalization with conventional development drivers. Spatial econometrics analysis confirms significant poverty spillovers across contiguous provinces (ρ=0.22; $p < 0.01$), indicating that local poverty dynamics are interlinked with neighboring regions. Fixed-effects panel regression and spatial econometrics analysis reveal statistically significant inverse associations between the Human Development Index (HDI) and poverty. Digitalization significantly reduces poverty only after HDI exceeds a threshold of 65 (β= -0.133; $p < 0.05$), confirming the critical role of human capital as a prerequisite. This study has practical implications, showing that the equally crucial expenditures in education, healthcare, and community capacity building contribute to closing the digital divide in Indonesia because digital inclusion depends on human capital. The phased strategy proposed emphasizes human capital as the fundamental component of efficient digital integration, supporting the philosophy of inclusive development.

Contribution/ Originality: This study presents a new approach based on a threshold that demonstrates digitalization decreases poverty only if human capital (HDI) exceeds a critical threshold. The Spatial Durbin Model and threshold regression enhance the capability approach by incorporating spatio-digital readiness into poverty reduction strategies.

1. INTRODUCTION

Still, emerging countries like Indonesia face structural problems that continually hinder their growth. Here, poverty remains the primary issue. Over the past ten years, the nation has experienced consistent economic growth; however, there are significant disparities in the distribution of development outcomes, particularly in Eastern Indonesia and other regions considered impoverished. Papua's poverty rate reached 26.03% (BPS, 2024), contrasting with the national average of 9.03% (BPS, 2024). BPS (2024) reports an average poverty rate of over 10%. The ten provinces with the highest poverty rates are 26.03 percent; Papua follows West Papua (20.49 percent), and East Nusa Tenggara (19.96 percent). While the national poverty rate has been decreasing overall, regional variations demonstrate a multidimensional development gap, including economic, social, and digital domains.

Geographical challenges include inaccessible archipelagos and inadequate infrastructure for transportation that abound in the eastern half of Indonesia, all of which aggravate present disparities in access to markets and basic services (BPS, 2024). Moreover, increasing social and economic isolation in already economically underdeveloped places is the digital divide. According to Rydzewski (2025), the differences in information and communication technology (ICT) infrastructure between urban and rural areas between the two communities constitute a primary barrier to a fair digital transformation. According to Nugroho, Dirgantari, and Hidayat (2022), such gaps restrict information access and hamper the involvement of the digital economy for vulnerable populations. This addresses digital financial services, e-commerce, and online learning among other industries.

Since it has always been under control, economic progress is one of the key engines commonly attributed to reducing poverty. According to Stiglitz (2016) and Van Kesteren, Smith, and Lee (2019), the trickle-down hypothesis maintains that the rise of employment possibilities and the transfer of money will finally aid groups with lower incomes through the growth produced by groups with higher incomes. Still, the success of this strategy is under question since not every development generates inclusive results. This is particularly true in economically underdeveloped places lacking sufficient human capital and infrastructure (Chen & Ravallion, 2020; Kakwani, 2014). Many studies have demonstrated that economic development, in the absence of advances in human capital and active involvement in the digital economy, has a predisposition to fall short in sustainably reducing poverty (UNCTAD, 2021).

While Rotondi, Stanca, and Tomaselli (2020) found that 80% of MSMEs in Indonesia lack internet access, this study integrates spatial spillovers and HDI thresholds, which were unaddressed in prior work. The literature suffers from gaps since much of the current research concentrates separately on one or two issues. For instance, Bala, Ibrahim, and Hadith (2020) investigate how unemployment and economic growth impact poverty; Miranda-Lescano, Muinelo-Gallo, and Roca-Sagalés (2023) confine their study to economic growth and HDI, thereby neglecting the part played by digitalization. These two studies examine the interactions between poverty and economic progress. The OECD (2019) underlines how successful the digital revolution can be only with enough infrastructure and digital literacy. Several of Indonesia's poorest regions still lack these criteria.

Analyzing the combined effects of economic growth, the Human Development Index (HDI), and e-commerce on poverty levels in the ten provinces in Indonesia recognized as the poorest from 2019 to 2023 is the aim of this study. Especially given the achievement of the Sustainable Development Goals (SDGs) in the digital era, this study intends to contribute to the discussion on inclusive development and to aid, both theoretically and practically, in building evidence-based policy. This is accomplished through a quantitative technique based on panel data.

This study offers three primary contributions that differ from previous research. First, it presents an integrative model by examining digitalization, economic growth, and the Human Development Index (HDI), which is not commonly done in developing countries, including Indonesia. Second, it employs spatial panel econometrics to measure poverty spillovers across regions, which may be important for reducing disparities in eastern Indonesia. Third, it empirically demonstrates that a specific HDI threshold (≥65) is a precondition for digitalization to positively affect poverty reduction, addressing a longstanding policy gap.

Down approximately 680,000 persons from March 2023, the national poverty rate in Indonesia declined to 9.03 percent as of March 2024 (BPS, 2024). With the national poverty rate dropping to 9.03 percent, current data on poverty reduction in Indonesia reveal positive patterns. Nevertheless, these developments still present challenging obstacles, particularly when the three basic dimensions economic development, human development, and digitalization fail to behave harmoniously. A development strategy with integrative and multidimensional aspects is crucial in formulating effective plans for lowering poverty.

While the significant effects on economic growth, human development, or digitalization are receiving increasing attention as individual factors in the poverty reduction literature, a comprehensive correlation among them is still underexplored in Indonesia's poorest provinces. The novelty of this study is its integrative approach, which

simultaneously considers the joint impacts of economic growth, the Human Development Index (HDI), and e-commerce activities on poverty reduction, employing advanced panel data and spatial econometric techniques. Moreover, this study contributes to the literature by bridging significant gaps through examining hidden value in underappreciated spatial and interaction analytical methods and revealing empirical evidence of digitalization threshold effects on various HDI levels and underdeveloped regions. Its academic significance lies in deepening theoretical discussions of inclusive development in the digital age, and its policy implications provide practical directions for designing integrated, multi-dimensional anti-poverty plans aimed at bridging economic disparities and the digital divide in Indonesia. In this way, this research can help inform Indonesia's contribution toward the SDGs in an equitable and sustainable manner.

Panel-based regional studies applying spatial econometric methods such as the one suggested in this research remain underrepresented in the body of knowledge on Indonesian development. Three significant gaps in the current body of knowledge are addressed in this work. First, no integrated model exists that methodically links digitalization, the Human Development Index (HDI), and economic growth. Second, spatial and interaction-based analytical techniques are underused, especially in underdeveloped areas, restricting understanding of regional differences. Third, there is still limited empirical data on the threshold effect of the efficacy of digitalization across various HDI levels. By closing these gaps, this research aims to contribute to a more comprehensive understanding of how digitalization might promote inclusive and sustainable development in Indonesia.

2. LITERATURE REVIEW

2.1. Review of Related Literature

An interest in poverty in Indonesia has been present for a considerable amount of time among academics at the national and local levels. The most recent research suggests that the most important factors in reducing poverty are the improvement of the economy and the development of the human population. By way of illustration, Pernia (2003) and Kakwani (2014) presented the idea of pro-poor development, which asserts that poverty can be significantly reduced by adopting economic growth that is both inclusive and of high quality. In the context of Indonesia, Zakaria (2024) finds that an increase in the regional GDP leads to a reduction in poverty, notably in the agricultural and informal sectors. The Human Development Index (HDI) is currently used to replace basic capacities in a significant study area. According to Yun (2024), findings show that gains in the Human Development Index (HDI) are significantly associated with greater well-being and reduced poverty levels. This is particularly true in areas with limited access to basic education and healthcare facilities.

Small-scale economic operators have become increasingly aware of the potential benefits of digitalization, particularly e-commerce, as a method of expanding their market access and enhancing profitability over the past 10 years. The widespread use of digital technology has been a driving force behind this increased awareness. This consciousness has been directed exclusively toward several studies (Bontis, 2001; Gromova, Timokhin, & Popova, 2020) that have concluded that the utilization of digital platforms has the potential to contribute to the promotion of equitable development. It is a warning against the digital gap, which can potentially worsen regional inequality, particularly in areas with low levels of computer literacy and insufficient infrastructure (Hilbert, 2016). The paper warns against the digital gap. Achieving equal development in Indonesia is challenging due to the country's dispersed geographical features. Because of this fragmentation, the possibility of socioeconomic spillovers, such as the propagation of poverty across several regions, has increased. Regarding the regional peculiarities of poverty in Indonesia, however, a limited number of studies have been conducted; most studies have relied on cross-sectional methodologies or national averages. Recent studies (Primayesa, Widodo, & Sugiyanto, 2023) suggest that expanding some businesses, such as tourism, may benefit the economies of the towns where these businesses are located. Furthermore, it has been demonstrated that increasing the per capita income in some provinces of Sumatra can reduce inequality in neighboring provinces (Resosudarmo, 2022).

On the other hand, there is the possibility that poverty will have adverse effects. According to Krishna (2019), the creation of spatial poverty traps long-term clusters of adversity can be attributed to several potential factors. These include social exclusion, institutional failures, inadequate infrastructure, and geographic isolation. Regarding the findings of research conducted by Kanagaratnam (2017), it has been observed that physically distinct regions within Indonesia can exhibit higher poverty rates, even when individual-level causes remain unchanged. The adverse neighborhood effect, reinforced by the fact that poor environmental conditions limit returns on investments in economic activity, education, and health, contributes to the worsening of this trend. Evidence from East Java suggests that the wealth of households in a single locality can significantly impact the economic outcomes of nearby districts, either boosting or decreasing the region's well-being (Vélez, Robalino, & Robles, 2022). The actions carried out must be spatially oriented to counteract these detrimental spillovers. These interventions are recommended to include investments in human resources, fundamental infrastructure, and regional policies that emphasize areas that are not adequately served (Krishna, 2019). Even though it is still working toward its national development goals, Indonesia runs the risk of establishing its spatial poverty traps because there are no remedies that are sensitive to spatial considerations.

The vulnerability of archipelago countries, such as Indonesia, to long-term poverty is emphasized by Gallup, Sachs, and Mellinger (1999). This vulnerability results from insufficient economic integration and high transportation costs. The low level of economic integration and high transportation costs are the sources of this liability. Resosudarmo (2022) argues that although inadequate infrastructure spreads poverty from one location to another, increased communication across islands can effectively minimize such scenarios' effects. Increasing communication between islands, lowering pricing inequalities, and enhancing logistical distribution were all goals intended to be accomplished by implementing the Sea Toll concept. According to Hill and Vidyattama (2008), connectivity gains lead to reduced poverty spillovers and increased positive externalities. This is accomplished by supporting the integration of formerly isolated places into national economic networks. According to Sandee (2015), regulatory reform, investments in specifically targeted infrastructure, and institutional coordination are required to achieve successful implementation.

2.2. Theoretical Framework

Three theoretical models are used in this study to understand poverty dynamics in underdeveloped areas of Indonesia.

2.2.1. Capability Methodology

Roberts et al. (2015) assert that poverty not only results in a loss of wealth but also in a deprivation of fundamental capacities that enable people to achieve desired functioning. The HDI offers a composite indicator for these basic requirements: health, education, and living standards. These skills are essential for properly embracing and benefiting from technology in the digital sphere.

2.2.2. Digital Division Theory

This theory holds that different social groups and sectors have different access to, use, and benefit from digital technology (Chadwick & Howard, 2009; Ragnedda & Muschert, 2013). Low digital literacy and poor ICT infrastructure systematically exclude some individuals from the advantages of digitalization. The digital divide appears to be significantly impeding Eastern Indonesia's plans for technologically based development (Hilbert, 2016; World Bank, 2023b).

2.2.3. Inclusive Development and Poverty Spill-Overs

The frameworks of Son (2007) and ESCAP (2025) stress the need for economic growth that encompasses the

underprivileged. Using trade, migration, and social networks, spatial methods also contend that poverty is interdependent, and conditions in one location can directly affect adjacent areas (Anselin, 2002).

These models, taken together, serve three basic purposes. They first question the boundaries of the linear trickle-down effect, which still directs most approved development paradigms. Second, they provide the idea of a capability threshold: the lowest degree of human development needed for effective digitalization. Third, they suggest a sequential policy framework whereby basic economic growth drives human capability development; then, poverty reduction occurs in stages, followed by digital transformation.

The strategy for decreasing poverty is considered both planned and cumulative, as Figure 1 illustrates. To build basic infrastructure, the initial phase requires economic development suitable for low-income populations. In the later stages, the primary driver of increasing individual and collective capacities is shifts in the Human Development Index (HDI). When the HDI exceeds a critical threshold—HDI > 65—digital initiatives, such as e-commerce and digital banking services, begin to play a significant role in reducing poverty.

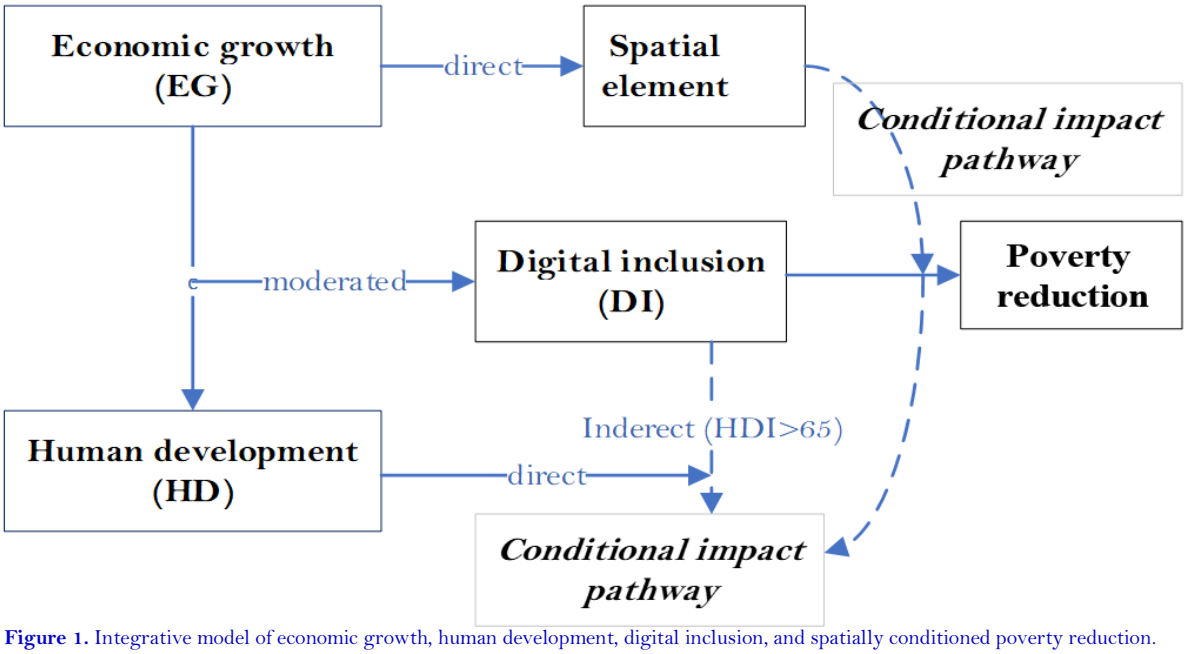

Figure 1. Integrative model of economic growth, human development, digital inclusion, and spatially conditioned poverty reduction.

2.3. Hypotheses and Conceptual Model

This paper suggests three basic hypotheses to be investigated empirically based on the above-mentioned theoretical framework.

H_1: Poverty is negatively linked with economic progress; this effect is strengthened in interaction with human development (HDI).

H_2: Only in areas where the HDI surpasses the 65th percentile can digitalization significantly help to reduce poverty.

H_3: The non-linear and conditional link exists between economic growth, HDI, and digitalization in determining poverty outcomes.

The created empirical model in this work addresses the critique of partial approaches common in the body of current research. Usually focusing on the elements of poverty reduction digitalization, human development, and economic growth inseparably, previous studies ignore their probable interactions. For example, research by Suryadarma and Sumarto (2013) and Miranda-Lescano et al. (2023) analyzes the relationship between economic growth and HDI, disregarding the role played by digitalization. While reports by Tadesse and Bahiigwa (2015) and Gurumurthy and Chami (2019) on the opportunities of e-commerce meanwhile overlook basic human capacities as a moderating factor.

Such divided points of view fall short in sufficiently capturing the complex interactions among several components in real-world surroundings, particularly in slow-moving locations with specific features. For instance, the apparent differences in digital infrastructure between Papua and West Nusa Tenggara (NTB) highlight the need for a combined analytical viewpoint. This paper emphasizes how one should view digitalization, human growth, and economic progress as mutually interrelated components of a single system. The ten worst provinces' empirical data from Indonesia enables one to assess the validity of this combined theoretical model.

2.4. Integration of Conceptual Models

Figure 2 illustrates the integrated model proposed in this work, where a minimal threshold of human potential and inclusive (pro-poor) economic growth satisfy two fundamental preconditions, enabling digitalization to serve as an effective tool for poverty reduction exclusively. The model also incorporates geographical aspects, recognizing that the poverty levels in surrounding areas may influence the success of digital interventions positively or negatively.

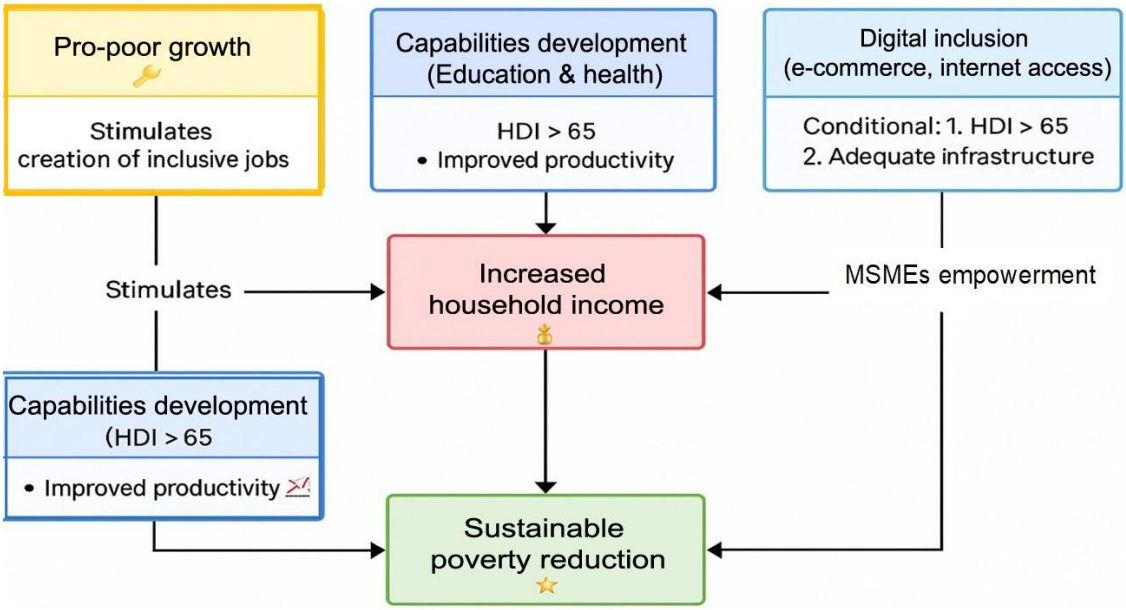

Figure 2. Integrative theoretical framework for poverty reduction.

Source: Developed by the author based on (Sen, 1999; World Bank, 2023b).

It is clear from this that there is an urgent need for a phased and spatially sensitive strategy for regional development in areas falling behind. There is also empirical evidence that lends weight to this notion. According to Kwak and Jain (2016), research has reported that implementing e-commerce platforms has reduced poverty.

According to Kakwani and Pernia (2000), traditional development frameworks often consider economic growth to be the primary factor in the success of poverty reduction efforts. Conversely, more recent research suggests that growth does not necessarily lead to inclusive outcomes. East Nusa Tenggara (NTT), despite experiencing a lower growth rate of 3.8%, achieved more substantial poverty reduction, primarily due to increases in HDI (BPS, 2024). For example, in Eastern Indonesia, Papua registered 5.2% growth in 2023 but still maintained a high poverty rate of 26%. East Nusa Tenggara (NTT) also saw no significant reduction in poverty. This contradiction suggests that economic expansion is only beneficial when accompanied by parallel advances in human capabilities, echoing the argument that (Medina-Moral & Montes-Gan, 2018) made regarding development as freedom.

However, the outcomes remain mixed, even though digitalization is regularly promoted as a modern solution for poverty. The adoption of e-commerce has been shown to increase the incomes of micro, small, and medium-sized enterprises (MSMEs) by up to 18% in rural China (Zhang & Zhao, 2025). As opposed to this, digital penetration

appears to increase inequality in locations such as West Papua, where only twenty percent of micro, small, and medium-sized enterprises (MSMEs) have access to dependable internet (Rotondi et al., 2020). Even if the percentage of people who have access to the internet reached 79.5% in 2024, the Indonesian Internet Service Providers Association (APJII) reports that the level of digital literacy among consumers is still very low. These disparities are typically the result of uneven infrastructural development and digital literacy, both of which are often overlooked in literature advocating for digital technology.

In previous studies, economic growth, human aptitude, and digitalization have typically been investigated in isolation. The reality is that these three dimensions operate within a system that is both complex and interrelated. For instance, the discovery that e-commerce interventions became statistically significant in NTT only after the Human Development Index (HDI) crossed 65 (β = -0.15; $p < 0.05$) indicates the presence of a capacity threshold, which is a minimum degree of human development that must be achieved before digital methods can be effective. Specifically, this work intends to solve this conceptual and empirical gap through the integrative model provided.

3. METHODOLOGY

3.1. Study Design and Data Collection

The 2019-2023 timeframe was strategically chosen for three key reasons: (1) it reflects post-COVID digital acceleration in Indonesia, with a 42% increase in e-commerce adoption (Rahman, 2025). (2) It aligns with strategic shifts in significant infrastructure policies, as indicated by the expanded coverage of the national Sea Toll Program. (3) The year 2023 is the latest with fully validated poverty data from BPS across all ten provinces, ensuring comprehensive temporal coverage and avoiding preliminary estimates.

The primary data used for collection are e-commerce metrics obtained from digitalization data in the Ministry of Communication and Information Technology's annual report, including the percentage of micro, small, and medium enterprises (MSMEs) with digital platforms; poverty figures; regional gross domestic product (GRDP); and the human development index (HDI), which are sourced from the annual BPS publication, namely Statistics of People's Welfare and Regional Statistics.

3.2. Conceptual Framework and Proxy Variables

For each variable in the research, the operational indicators are as follows:

Table 1. Each variable's proxy or indication.

Variable	Proxy/Indicator	Scientific justification
Poverty	Percentage of the poor population relative to the total provincial population	Standardized by BPS (2024) for cross-province comparability; excludes transient shocks
Economic growth	Annual real GRDP growth rate (in percentage)	Controls for inflation effects; preferred by the World Bank (2023a) for poverty-growth elasticity
HDI	Composite index (Education, health, expenditure)	Aligns with UNDG SDG indicators; captures multidimensional capacity gaps (Sen, 1999)
Digitalization	The percentage of MSMEs actively using digital platforms is defined as MSMEs with ≥1 monthly transaction on platforms.	Ministry benchmark for 'active users'; filters nominal adoption (Rotondi et al., 2020)

Table 1 presents the operationalization of variables used in this study, their proxy/indicator, and their scientific justification. Proxy selection adhered to two principles: policy relevance and theoretical congruence. For example, the e-commerce metric (≥1 transaction/month) was prioritized over binary internet access to avoid overestimating readiness—a limitation noted in OECD (2019). Similarly, real GRDP growth (vs. nominal) isolates actual economic expansion from inflationary noise.

3.3. Model Estimation

This work uses the Hausman and Chow tests to ascertain the most suitable model. While the Hausman test guides between FEM and the Random Effects Model (REM) by determining if unobserved individual effects are connected with the independent variables (Hausman, 1978), the Chow test separates the pooled OLS model from the Fixed Effects Model (FEM). Both tests produced findings that supported the FEM specification, which is therefore the primary model selected. FEM performs better than REM in terms of statistical fit and bias correction and considers unobserved heterogeneity between provinces; therefore, it is especially appropriate for our study.

Fixed Effects Model (FEM) over Random Effects was chosen when the Hausman test was statistically significant ($p < 0.01$). This strategy addresses the potential omitted bias in time-invariant unobserved heterogeneity across provinces, which is crucial since, for example, Papua and Maluku are culturally and geographically distinct regions. If omitted, this could bias estimates (Gurka, Kelley, & Edwards, 2012). The fixed effects regression model has the following overall form:

$$Poverty_{it} = \alpha + \beta_1 Growth_{it} + \beta_2 HDI_{it} + \beta_3 Digital_{it} + \mu_i + \epsilon_{it} \quad (1)$$

Inspired by Van Dijk's (2017) digital divide theory, this interaction term (HDI × Digitalization) tests whether human capital moderates the effect of digitalization on poverty reduction.

$$Poverty_{it} = \alpha + \beta_1 Growth_{it} + \beta_2 HDI_{it} + \beta_3 Digital_{it} + \beta_4 (HDI_{it} \times Digital_{it}) \mu_i + \epsilon_{it} \quad (2)$$

Inspired by the capability approach (Sen, 1999), this interaction-based framework argues that a minimal level of human capacities determines whether technology can effectively reduce poverty.

3.4. Spatial Model SDM

Beyond internal provincial considerations, this study also examines likely spatial spillover effects in the distribution of poverty, a particularly significant issue in Indonesia given its scattered topography and ongoing interprovincial inequity. Ignoring such geographical links could lead to erroneous policy advice and biased forecasts.

We account for spatial autocorrelation using the Spatial Durbin Model (SDM), which is preferred over the SAR/SEM counterparts based on highly significant likelihood ratio tests ($p < 0.05$). SDM can simultaneously consider endogenous spillovers (e.g., poverty clustering) and exogenous diffusion dynamics (e.g., HDI/digitalization spreading) as a requirement to represent Indonesia's intricate development behavior. To capture the archipelagic network structure, a Queen Contiguity weight matrix is utilized, in which the island itself is considered a connected entity, with sea-adjacent provinces like Papua and Papua Barat acting as neighbors. This approach recognizes that various provinces are connected through intensive inter-provincial networks, contrary to solely land-based contiguity (Elhorst, 2014; Resosudarmo, 2022).

This model captures how local poverty levels may be affected by local variables and situations in nearby provinces, thereby enabling the identification of both direct and indirect (spillover) effects from neighboring provinces. SDM is therefore used as a robustness check to investigate the spatial component of poverty dynamics (Zhang & Xu, 2023). The general SDM equation is specified as:

$$Poverty_{it} = \rho W Poverty_{it} + X_{it}\beta + WX_{it}\theta + \mu_i + \epsilon_{it} \quad (3)$$

Where:

W is the spatial weight matrix, constructed using queen contiguity to capture adjacency between provinces.

ρ represents the spatial autoregressive coefficient, indicating poverty spillover effects.

WX_{it} accounts for the indirect effects of independent variables in neighboring provinces.

3.5. Under presumptions Model Diagnostics and Testing

Several diagnostic tests were conducted, as shown in the table below, to ensure the reliability of the regression results. Table 2 provides a summary of the diagnostic tests and their outcomes.

Table 2. Model diagnostic test summary.

Assumption	Result
Multicollinearity	All VIF < 2 → no multicollinearity issue
Heteroskedasticity	Breusch-Pagan test is not significant.
Autocorrelation	Wooldridge test is significant → robust SE applied.
Spatial dependence	Moran's I test is significant ($p < 0.01$)

Source: Gujarati (2003), Wooldridge (2010), Breusch and Pagan (1979), Hausman (1978), Moran (1950), and Anselin (2003).

3.6. Robustness Checks

Threshold regression, as described by Hansen (2000), was used to determine the breakpoints of HDI and to prevent arbitrary classifications. This approach aligns with Sen's capability theory, which assumes that a certain minimum threshold is necessary to broaden the function an individual can achieve. This assumption cannot be tested through linear models (Kakwani, 2014). Several alternative models were also estimated to assess the sensitivity of the main results; however, this is beyond the scope of the article. A summary of these models is given in Table 3.

Table 3. Summary of additional models for robustness checks.

Model	Purpose
Dynamic GMM	Controls for potential endogeneity and persistence in poverty
SARAR	Addresses spatial autocorrelation and simultaneous error processes.
Threshold regression	Identifies HDI thresholds for digitalization to be effective.

Source: Hansen (2000), Arellano and Bond (1991) and Elhorst (2014).

4. RESULTS

4.1. Primary Results: Panel Regression with Fixed Effects

Using a panel data regression utilizing the Fixed Effects Model (FEM) in response to economic progress, human development (HDI), and digitalization (as proxied by e-commerce adoption), this paper assesses poverty levels among the ten lowest provinces in Indonesia for the period 2019–2023.

Table 4. Estimates of fixed effects models.

Variable	Coefficient	Std. error	p-value	Interpretation
Economic growth	-0.214	0.051	0.000	A 1% increase in GDP reduces poverty by 0.214%.
Human Development Index (HDI)	-0.149	0.035	0.000	A 1-point increase in HDI reduces poverty by 0.149%.
E-commerce (Digitalization)	-0.069	0.042	0.110	Not statistically significant.

Source: Result Analysis.

Table 4 presents the estimates of fixed effects models. The model explains over 67% of the variance in provincial poverty rates during the study, with an R-squared value of 0.675. These results support previous research that emphasizes the significant contribution of human and financial growth to reducing poverty (Kakwani, 2014; Sen, 1999). While the direct e-commerce effects are insignificant (p=0.110), its interaction with HDI becomes pivotal post-threshold, highlighting the limitations of isolated digital interventions in low-HDI regions.

4.2. Spatial Analysis: The Spatial Durbin Model (SDM)

To account for any interregional effects or spatial spillovers, the analysis was extended using the Spatial Durbin Model (SDM) as a robustness check for the original model (Yang, Noah, & Shoff, 2015).

Table 5. Spatial Durbin model results.

Variable	Coefficient	p-value	Interpretation
Economic growth (ΔGRDP)	-0.15	0.001	Still negatively associated with poverty.
Digitalization	-0.05	0.082	Marginally significant; digital effects are beginning to emerge.
Spatial spillover (ρ)	0.22	0.000	Poverty in neighboring provinces increases local poverty by 0.22 percentage points.

Source: Result Analysis.

Table 5 shows the results of using the Spatial Durbin model. The spillover effect (ρ=0.22) underscores the urgency of cross-province initiatives such as the Papua-West Papua Economic Corridor, which targets infrastructure gaps that drive spatial poverty traps. The spillover effects are especially evident in Papua, East Nusa Tenggara (NTT), and Aceh, where regional poverty patterns typically cluster spatially.

4.3. Robustness Checks

Table 6 presents the three supplementary models that were used as robustness checks to help increase the empirical validity of the results. First, an approach often employed in the study of non-linear correlations in inclusive development studies (Hansen, 2000), a Threshold Regression was used to determine the HDI level required for digitalization to considerably lower poverty. Second, unobserved spatial errors were considered using the SARAR model (Spatial Autoregressive Model with Autoregressive Disturbances), allowing a more exact estimate of pure spatial effects (Elhorst, 2014). Third, to address potential endogeneity a common issue in growth-poverty models a Dynamic GMM (Generalized Method of Moments) estimator was employed to record long-term poverty persistence (Arellano & Bond, 1991).

The HDI threshold results reveal that digital gains cannot be enjoyed without basic essential capabilities access to education, healthcare, and ICT infrastructure. The third hypothesis asserted that the interactions of digitalization, human development, and economic growth on poverty are non-linear and conditioned.

This hypothesis was tested using the threshold regression model. Results show that the impact of digitalization on poverty reduction becomes statistically significant only after HDI surpasses a threshold value of 65.2 ($\beta = -0.133$; $p < 0.05$). This supports the proposition that digitalization depends on minimum levels of human capability, thereby empirically validating the non-linear and conditional relationship stated in H3. Accordingly, Hypothesis 3 is confirmed in the context of Indonesia's ten poorest provinces during the 2019–2023 period.

Table 6. Robustness model results.

Model	Objective	Key findings
Threshold regression	Identify the HDI threshold for digitalization effectiveness.	E-commerce becomes effective only when HDI > 65
SARAR	Control for unobserved spatial error	Spillover effect remains significant (λ = 0.18)
Dynamic GMM	Capture long-term poverty persistence	40% of poverty persists from one year to the next

4.4. Policy Implications

The empirical findings of this study offer several strategic insights for designing development policies in Indonesia's lagging regions. Table 7 presents a summary of the policy implications of this study.

A compelling example can be observed in East Nusa Tenggara (NTT), where digitalization only became effective after the HDI surpassed 68 and internet access reached most areas. In contrast, provinces like Papua and Aceh experience persistent poverty due to low HDI levels and negative spatial spillovers from adjacent regions.

Table 7. Summary of policy implications.

Key finding	Policy recommendation
Significant impact of growth	Strengthen labor-intensive sectors and promote local economic development.
Strong role of HDI	Prioritize basic education, maternal and child health, and literacy programs.
Digitalization is not yet effective.	Invest in internet infrastructure; subsidize training and access to digital tools.
High spatial spillover effect	Foster interprovincial coordination through collaborative regional development frameworks.

4.4.1. The Part Economic Development Plays in Reducing Poverty

With a score of -0.15, economic development remains a statistically significant factor in reducing poverty in the ten worst areas of Indonesia. This result is logical. World Bank (2023b) statistics show a 0.2% decline in extreme poverty in emerging nations, which correlates with a 1% increase in per capita GDP. The key mechanisms at work include job development, increased real wages, and improved access to essential services such as health and education. Social protection initiatives have also played a significant role by enhancing the resilience of underprivileged households improving incomes, expanding access to services, and providing buffers against economic and environmental shocks thereby improving incomes, expanding service access, and mitigating environmental shocks.

Expanding agriculture and MSME sectors as seen in NTB and Gorontalo has notably had a greater impact on lowering poverty than development in extractive industries, thanks to higher labor absorption and stronger local economic links. Public works projects combined with strategic stimulus such as National Strategic Projects in Papua have helped reduce poverty annually by 0.5%, according to the Ministry of Finance 2023.

The effectiveness of expansion, meanwhile, is not always apparent. Rising inequality Gini ratio increased from 0.38 to 0.41 over the past five years has impeded the distributional benefits of development (BPS, 2024) in provinces such as Aceh and Papua. There is a "jobless growth" tendency in sectors like mining in West Papua, which grew by 5% annually but accounted for just 2% of total employment (Sugiarti, Yunianto, Damayanti, & Hadijah, 2021). Moreover, the spatial spillover coefficient ($\rho = 0.22$) implies that unskilled migration could unintentionally increase poverty in origin provinces by utilizing development in neighboring areas. For example, development in Southwest Papua has attracted West Papua migrants. However, without corresponding skill development, migrants may find low-paying seasonal jobs without social safety nets. Therefore, growth is insufficient; inclusive, spatially aware policies should accompany it.

Maximizing the prospects for reducing poverty through development depends on three policy directions: supporting labor-intensive sectors through performance-based fertilizer subsidies and adaptive skills training in digital and green economy sectors. One can reduce inequality by improving the targeting systems in social assistance programs, notably by orienting the Family Hope Program (PKH) towards poor households in Papua and linking Village Cash Transfers (BLT Desa) to participation in vocational training. Use physical connectivity roadways linking Papua and West Papua and varied minimum wages matched with local living expenses to regulate geographical dynamics.

In the end, while economic development has considerable potential to reduce poverty, its success mainly depends on the quality of growth and the supporting political system. The advantages are concentrated among a small group that lacks sufficient initiatives toward equitable growth and spatial justice. These findings highlight the need for evidence-based, culturally responsive strategies to build successful poverty-reduction efforts for Indonesia.

4.4.2. The Impact of the Human Development Index (HDI) on Poverty Reduction

The Human Development Index (HDI) quantifies human development, statistically significantly and robustly impacting poverty reduction in Indonesia's most impoverished provinces. The results are from the global

development literature, as they indicate that poverty reduction is 0.149% for each one-point increase in HDI. The primary mechanisms through which this effect operates are HDI's three pillars education, health, and income. Education enhances labor productivity, health mitigates household vulnerability, and income expands economic opportunities. One well-known project demonstrating successful local government and university campus cooperation in rapid digital transformation at the village level is the "Village Information and Digitalization Pioneer" project in West Lombok. Although HDI is sometimes used as a surrogate for social development, its contribution to decreasing poverty is not without debate. For example, although rural areas remain largely lacking in basic services, HDI rises mostly in urban areas about 72% of development benefits (World Bank, 2016). This highlights how poorly HDI considers geographic isolation and spatial vulnerability, two important elements affecting welfare outcomes in remote areas. Moreover, the attack is HDI's component on education, which stresses inputs such as average years of education instead of the fit between educational outputs and labor market demand (Kuntjorowati, Rahardjo, & Santosa, 2024). For Aceh, for example, better HDI ratings have not matched declining poverty rates. Curricula run counter to local economic realities, and outmigration of educated workers has slowed structural change and increased social inequality. Contextually aware and multidimensional approaches are essential to improve the efficacy of HDI. Targeted health initiatives and contextually relevant vocational education should take the forefront in areas with low Human Development Index (HDI). Improving access to digital finance and building real-time monitoring systems could be more suitable for medium-HDI areas. Equally important is the reform of HDI measurement, which uses comprehensive well-being indicators and develops policies aimed at reducing brain drain.

In summary, even if the Human Development Index (HDI) is necessary for reducing poverty, its effectiveness depends on precise application, comprehensive support policies, and a more integrated measurement framework. Human growth must be viewed as a complex process encompassing environmental sustainability, equity, local relevance, and more than just numerical indicators.

4.4.3. E-Commerce (Digitalization)

E-commerce has significant potential as a poverty-reduction mechanism in Indonesia's impoverished provinces; however, its effectiveness varies across regions. Several studies support the positive role of digitalization and e-commerce, particularly in reducing poverty. For example, Ye, Chen, and Li (2022) demonstrated that improved access to ICTs has been a key driver of poverty reduction in various provinces in China. The 2024 "Poverty, Prosperity, and Planet" Report by the World Bank also emphasizes digital inclusion as a fundamental element of inclusive development, although it does not provide specific numerical estimates.

This study demonstrates that an increase of one point in the e-commerce penetration index reduces poverty. These results also align with the World Bank (2024), which states that digital platform use increased MSME income by 12-18%. Nevertheless, the e-commerce windfall is anything but equitable. Three main barriers inhibit the potential value of the technology: a) The digital divide gaps are still vast, with only 23 percent of people experiencing poverty in Papua and NTT having sufficient internet access to engage in online commerce; b) Dependence on large platforms that charge high commission fees (15-30%) is impacting traders, with poor MSMEs losing an average of 27-31% of their profit margin; c) Low digital literacy and fundamental digital skills 68% of targeted MSME owners reside in the bottom quintile of regions and find it difficult to operate digital payment systems.

These worries cannot be addressed unless a policy mix at the system level is implemented, which includes, inter alia, the fast-track development of digital infrastructure in rural areas; sensible platform economics that do not excessively inhibit the profit-making of MSMEs from the platforms; and the integration of digital entrepreneurship curricula with vocational educational systems to address these concerns effectively.

The development of these policies and their operationalization need to be adaptable to the context and must be mainstreamed into development activities. E-commerce has the potential to significantly alleviate poverty; however, to realize this potential, a multi-pronged approach that considers infrastructure readiness, capacity building among

people, and a proper regulatory environment must be adopted. This aligns with the Diana, Mascia, Tomczyk, and Penna (2025) digital divide model, which posits that the benefits of digitalization can only be equitably achieved if disparities in access and skills are reduced.

5. DISCUSSION

By embedding digital literacy as a core dimension of Sen's capabilities, this study redefines 'freedom' in the digital age, where access to technology enables economic agency. Four significant theoretical contributions are identified from the integrative model built, which push the boundaries of current developmental frameworks.

Indeed, the study is consistent with the emergent concept of the Digital-Enabled Trickle-Down Mechanism (DETDM). It assumes that the rewards from economic growth can truly penetrate people with low incomes if accompanied by positive changes in human development (especially in education and health) (World Health Organization (WHO), 2023) and market access (Weltbank, 2023) which in turn are associated with the market condition ($\rho = 0.22$), that can serve either as enablers or constraints in growth redistribution (Anselin, 2003). This means that in digital environments, economic growth is not a sufficient condition to decrease poverty if it is associated with capability threshold levels and digital infrastructure.

Second, the research advances Amartya Sen's capability approach by incorporating digital capability as a key dimension of contemporary human development (Sen, 2021). The effect modification of the HDI and e-commerce illustrated by the significant, negative interaction coefficient (-0.008*) indicates that the success of digitalization in poverty reduction largely depends on reaching a threshold level of basic capabilities (World Health Organization (WHO), 2023). These are the inclusions of a multidimensional nature of poverty (Alkire, Kanagaratnam, & Suppa, 2023), and they suggest including digital dimensions in a modern capability theory.

Third, the study develops spatial-economic theory by unifying Myrdal's spatial structure theory of the backwash effect and a spatial equilibrium model (Fujita, Krugman, & Venables, 1999). To that end, it proposes a new concept the poverty spillover elasticity and demonstrates how the digital revolution can help reduce the negative spatial dependencies between regions. This observation fills a void in the development literature, where much attention has ignored the spatial externalities of digital exclusion (OECD, 2019).

The study provides empirical evidence for updating Lewis's dual economy theory to the digital era. The structural change from conventional to modern sectors is found to depend not only on the accumulation of human capital but also on the existence of a 'digital bridge' that links both sectors (International Labour Office, 2021). Rates of labor absorption into modern sectors are retarded by a digital divide (ADB, 2023), implying that traditional dualism has to admit technological change as a primitive variable of the field (World Bank, 2023a).

From these theoretical insights, three further policy implications are proposed: redesigning the measurement of poverty by adopting a multidimensional digital poverty index, the Multidimensional Digital Poverty Index that integrates access and quality of growth and space network effects (Ruiu & Ragnedda, 2024). Support the digital-spatial development process, especially considering the local comparative advantage and mitigating the impact of regional spillovers (Panori, 2024). Phase in digital deprivation alleviation (Digital Deprivation Ladder) begins at the grassroots level and progresses toward full integration into the digital economy (UN ESCAP, 2020).

Despite its strengths, the study has several limitations. First, it adopts a static panel data method; therefore, future research can address dynamic spatial panel models to incorporate more geographic information into digital indicators (Elhorst, 2014). Second, the challenge of cross-national comparison tests the model's generalizability (Silver & Li, 2025). Third, evidence must be generated through policy experiments to test the efficacy of digital interventions in real-world practice settings.

This integrative model has been empirically confirmed and is consistent with Digital Human Capital Theory (Becker, 2021), emphasizing the interactions between human capital, digital technology adoption, and spatial agglomeration. ILD effects are supported by World Bank (2023a) data for 15 developing countries that confirm

significant interactions between GDP and digitalization effects, together with stable spatial spillovers. At the micro level, based on data from the national survey (BPS, 2024), MSMEs that engage in e-commerce have a significant increase in their revenues, particularly by improving their formal education capacity for running the business. However, the model is difficult to implement. Geographical imbalances also manifest as spatial challenges; for example, Papua will need three times more investment in digital infrastructure than the national average (Tonggiroh, 2017). Institutions face inadequate intersectoral coordination and low local governance capacity (KemenPAN-RB, 2023; LPEM, 2023). Sociocultural barriers, including resistance to technology in traditional societies and gender imbalances in digital access (only 32% of digital MSMEs are female-led), also limit adoption (OECD, 2019).

This requires robust computer literacy programs that help in decision-making and meet the needs that arise from increased use of technology (Buchan, Bhawra, & Katapally, 2024). Incorporating digital literacy into the education process is a key factor in helping to produce future graduates and combat digital exclusion, as the absence of digital literacy can mean an inability to participate fully in digital life (Reddy, Chaudhary, & Hussein, 2023). A multi-pronged strategy is necessary to counter these threats. Therefore, the application of the Digital Growth Pole policy must be aligned with the region's potential. Establish the Multiple-Use Cluster by creating the Digital Task Force, and develop a real-time productivity measurement system (Reddy et al., 2023). Therefore, inclusive programmes that promote digital literacy and extend special incentives toward women-led MSMEs will be a top priority (Buchan et al., 2024; Mejías-Acosta, Regnault, Vargas-Cano, Cárdenas-Cobo, & Vidal-Silva, 2024). This may contribute to equitable digital health uptake by improving digital literacy skills, which consider the perspectives of all stakeholder groups, such as consumers, advocacy groups, healthcare workers, policymakers, researchers, and industry (Campanozzi et al., 2023).

Even if the resulting integrated model has a strong theoretical and empirical basis, it depends on how and to what extent it can be locally adapted to particular socio-economic and geographical conditions. Of course, there is no one-size-fits-all solution; only the dynamic and context-specific application of the model's elements can significantly help lower poverty in the digital age.

6. CONCLUSION

This research indicates that a joint and coordinated approach is necessary to combat poverty in Indonesia's ten poorest provinces. It will specifically focus on addressing three fundamental areas: inclusive economic growth, human development (HDI), and digital transformation, with the unique conditions of each province guiding the application of a spatial approach.

The results conclude that economic growth of 0.15% against a 1% improvement in GDP can decrease poverty, but both must improve simultaneously with HDI efforts, digital technology, and information. Digital accessibility and digital infrastructure, partly driven by e-commerce, could effectively tackle poverty regionally. However, numerous challenges exist, ranging from infrastructure shortages to very low digital literacy in almost all regions.

The empirical results suggest that the development and digital era should have a threshold that positively affects poverty. At the same time, in the present case, economic growth is found to positively impact poverty only in conjunction with improvements in the Human Development Index and digital permeability.

The offered integrative framework, characterized by a combination of the concepts of pro-people growth, human capacity development, and digital engineering with space logic, indicates that removing poverty depends on internal provincial factors and external regional dynamics.

On one hand, economic development is non-stimulating without progress in human capital and digital spillovers. Digital information is limited when HDI is below 65. Moreover, the spillover effects and their spatial spillover elasticities confirm the presence of poverty spillovers, which indicate regional welfare development.

Theoretically, the article proposes the development capability threshold model and extends it to spatial contexts. This has practical implications, as new opportunities emerge for developing evidence-based interventions designed

to be scalable and tailored to the features of socio-economic development. Nevertheless, the interventions must be policy-flexible to ensure that regional poverty reduction models are effective.

The problem is that policies that are rigidly designed but not adaptive will not produce the best results, as the acceptable poverty threshold will be reshaped by digital technology. In this regard, policy

7. RECOMMENDATIONS

It describes the priority strategic paths to accelerate poverty reduction, especially in the country's most impoverished provinces:

- Create a Multidimensional Digital Poverty Index based on access/distance to digital services, technical literacy, and spatial connectivity. The HDI must also be improved to deliver digital health interventions, particularly in provinces with low HDI, such as Papua, NTT, and Maluku.
- Embrace a spatial-digital integrated development planning approach using Digital Growth Poles, which correspond to local potential and content to drive near policies, including inter-provincial spillovers. We want a geospatial monitoring system to oversee regional interconnectivity, most notably in Eastern Indonesia.
- Prioritize context-specific digital hubs in Eastern Indonesia, where subsidized internet, vernacular language training, and e-commerce logistics are all geared toward female-led MSMEs.
- Strengthen institutional measures to establish a Digital Poverty Reduction Task Force, implement real-time monitoring systems, and expand inclusive digital literacy programs targeting women, Aboriginal people, and the rural population in remote provinces.
- About the application, future research may consider constructing dynamic spatial panel models, conducting comparative analyses, and policy experiments that can help policymakers identify the most effective type of digital intervention.
- The realization of poverty reduction in the ten provinces is also expected to serve as the primary reference for gauging whether digital transformation efforts can be widely implemented as an inclusive and sustainable development tool in Indonesia.

Funding: This study received no specific financial support.
Institutional Review Board Statement: Not applicable.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, and that no key aspects of the investigation have been omitted. Any differences from the study as planned have been clarified. This study adhered to all writing ethics.
Data Availability Statement: Upon a reasonable request, the supporting data of this study can be provided by the corresponding author.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

REFERENCES

ADB. (2023). *Development effectiveness review.* Retrieved from https://www.adb.org/sites/default/files/institutional-document/963271/2023-development-effectiveness-review.pdf

Alkire, S., Kanagaratnam, U., & Suppa, N. (2023). *The global multidimensional poverty index (MPI): 2023 Revision (OPHI MPI Methodological Note No 55).* Oxford, UK: Oxford Poverty & Human Development Initiative, University of Oxford.

Anselin, L. (2002). Under the hood: Issues in the specification and interpretation of spatial regression models. *Agricultural Economics, 27*(3), 247–267. https://doi.org/10.1111/j.1574-0862.2002.tb00120.x

Anselin, L. (2003). Spatial econometrics. In B. H. Baltagi (Ed.), A companion to theoretical econometrics. In (pp. 310–330). Hoboken, NJ, United States: Wiley-Blackwell

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies, 58*(2), 277–297. https://doi.org/10.2307/2297968

Bala, U., Ibrahim, A., & Hadith, N. B. (2020). Impact of population growth, poverty, and unemployment on economic growth. *Asian Business Research Journal*, *5*, 48–54. https://doi.org/10.20448/journal.518.2020.5.48.54

Becker, G. S. (2021). *Digital human capital: Theoretical foundations and empirical applications*. Chicago, IL: University of Chicago Press.

Bontis, N. (2001). Assessing knowledge assets: A review of the models used to measure intellectual capital. *International Journal of Management Reviews*, *3*(1), 41–60. https://doi.org/10.1111/1468-2370.00053

BPS. (2024). *Labor force conditions in West Papua Province [Report]*. Manokwari, Indonesia: Central Bureau of Statistics of Indonesia.

Breusch, T. S., & Pagan, A. R. (1979). A simple test for heteroscedasticity and random coefficient variation. *Econometrica*, *47*(5), 1287–1294. https://doi.org/10.2307/1911963

Buchan, M. C., Bhawra, J., & Katapally, T. R. (2024). Navigating the digital world: Development of an evidence-based digital literacy program and assessment tool for youth. *Smart Learning Environments*, *11*(1), 1-8. https://doi.org/10.1186/s40561-024-00293-x

Campanozzi, L. L., Gibelli, F., Bailo, P., Nittari, G., Sirignano, A., & Ricci, G. (2023). The role of digital literacy in achieving health equity in the third millennium society: A literature review. *Frontiers in Public Health*, *11*, 1109323. https://doi.org/10.3389/fpubh.2023.1109323

Chadwick, A., & Howard, P. N. (2009). *Routledge handbook of internet politics*. London: Routledge.

Chen, S., & Ravallion, M. (2020). *Reconciling the conflicting narratives on poverty in China* (NBER Working Paper No. 28147). Cambridge, MA: National Bureau of Economic Research. https://www.nber.org/papers/w28147

Diana, M. G., Mascia, M. L., Tomczyk, Ł., & Penna, M. P. (2025). The digital divide and the elderly: How urban and rural realities shape well-being and social inclusion in the Sardinian context. *Sustainability*, *17*(4), 1718. https://doi.org/10.3390/su17041718

Elhorst, J. P. (2014). *Spatial econometrics: From cross-sectional data to spatial panels*. New York: Springer.

ESCAP. (2025). *Urban transformation in Asia and the Pacific: From growth to resilience*. United Nations: ESCAP.

Fujita, M., Krugman, P., & Venables, A. J. (1999). *The spatial economy: Cities, regions, and international trade*. Cambridge, MA, United States: MIT Press.

Gallup, J. L., Sachs, J. D., & Mellinger, A. D. (1999). Geography and economic development. *International Regional Science Review*, *22*(2), 179–232. https://doi.org/10.1177/016001799761012334

Gromova, E., Timokhin, D., & Popova, G. (2020). The role of digitalisation in the economic development of small innovative enterprises. *Procedia Computer Science*, *169*, 461–467. https://doi.org/10.1016/j.procs.2020.02.224

Gujarati, D. N. (2003). *Basic econometrics* (4th ed.). New York: McGraw-Hill.

Gurka, M. J., Kelley, G. A., & Edwards, L. J. (2012). Fixed and random effects models. *Wiley Interdisciplinary Reviews: Computational Statistics*, *4*(2), 181–190. https://doi.org/10.1002/wics.201

Gurumurthy, A., & Chami, N. (2019). *Digital justice: Key concepts and frameworks for the Global South*. Bengaluru, India: IT for Change.

Hansen, B. E. (2000). Sample splitting and threshold estimation. *Econometrica*, *68*(3), 575–603. https://doi.org/10.1111/1468-0262.00124

Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica*, *46*(6), 1251–1271. https://doi.org/10.2307/1913827

Hilbert, M. (2016). The bad news is that the digital access divide is here to stay: Domestically installed bandwidths among 172 countries for 1986–2014. *Telecommunications Policy*, *40*(6), 567–581. https://doi.org/10.1016/j.telpol.2016.01.006

Hill, H., & Vidyattama, Y. (2008). Indonesia's changing economic geography. *Bulletin of Indonesian Economic Studies*, *44*(3), 407–435.

International Labour Office. (2021). *World employment and social outlook 2021: The role of digital labour platforms in transforming the world of work*. Geneva, Switzerland: International Labour Organisation (ILO).

Kakwani, N. (2014). Pro-poor growth and policies. In The Oxford Handbook of Africa and Economics. In (pp. 1–24). Oxford, UK: Oxford University Press

Kakwani, N., & Pernia, E. M. (2000). What is pro-poor growth? *Asian Development Review*, *18*(1), 1–16. https://doi.org/10.1142/S0116110500000014

Kanagaratnam, U. (2017). Macro, household, and individual level explanations for the geographic differences in poverty levels in Indonesia, 2000–2009. Doctoral Dissertation, University of Oxford.

KemenPAN-RB. (2023). *Bureaucratic reform roadmap 2020–2024*. Jakarta: KemenPAN-RB.

Krishna, A. (2019). Where are the poor and where are the poverty traps? A spatial approach. *World Development*, *115*, 1–12.

Kuntjorowati, T., Rahardjo, M., & Santosa, D. (2024). Rethinking human development metrics: A regional perspective on education and labor market Mismatch. *Journal of Development Studies*, *60*(3), 345–362.

Kwak, D.-H., & Jain, H. (2016). The role of Web and e-commerce in poverty reduction: A framework based on ecological systems theory. In V. Sugumaran, V. Yoon, & M. J. Shaw (Eds.), E-Life: Web-Enabled Convergence of Commerce, Work, and Social Life (Lecture Notes in Business Information Processing). . In (Vol. 258, pp. 143–154). Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-319-45408-5_12

LPEM, F. U. (2023). *Indonesia economic outlook 2023: Strengthening institutions for sustainable growth*. Jakarta: Institute for Economic and Social Research, Faculty of Economics and Business, University of Indonesia.

Medina-Moral, E., & Montes-Gan, V. J. (2018). Economic freedom, good governance and the dynamics of development. *Journal of Applied Economics*, *21*(1), 44–66. https://doi.org/10.1080/15140326.2018.1526873

Mejías-Acosta, A., Regnault, M. D., Vargas-Cano, E., Cárdenas-Cobo, J., & Vidal-Silva, C. (2024). Assessment of digital competencies in higher education students: Development and validation of a measurement scale. *Frontiers in Education*, *9*, 1497376. https://doi.org/10.3389/feduc.2024.1497376

Miranda-Lescano, R., Muinelo-Gallo, L., & Roca-Sagalés, O. (2023). Human development and decentralization: The importance of public health expenditure. *Annals of Public and Cooperative Economics*, *94*(1), 191–219. https://doi.org/10.1111/apce.12373

OECD. (2019). *Measuring the digital transformation: A roadmap for the future*. France: OECD Publishing.

Panori, A. (2024). *Digitally disrupted space: Proximity and new development opportunities for regions and cities*. San Diego, CA, United States: Elsevier—Smart Cities Series.

Pernia, E. M. (2003). *Pro-poor growth: What is it and why is it important?* (ERD Policy Brief No. 17). Manila, Philippines: Asian Development Bank.

Primayesa, E., Widodo, W., & Sugiyanto, F. X. (2023). Tourism spatial spillover effect and economic growth in Indonesia. *Economy of Regions*, *19*(4), 1161–1176. https://doi.org/10.17059/ekon.reg.2023-4-16

Ragnedda, M., & Muschert, G. W. (2013). *The digital divide: The internet and social inequality in an international perspective*. London: Routledge.

Rahman, A. (2025). *Digitalization of public services: An information technology approach for ministries*. Jakarta: Ministry of Information Technology Publishing.

Reddy, P., Chaudhary, K., & Hussein, S. (2023). A digital literacy model to narrow the digital literacy skills gap. *Heliyon*, *9*(4), e14878. https://doi.org/10.1016/j.heliyon.2023.e14878

Resosudarmo, B. P. (2022). Infrastructure development in Eastern Indonesia: Challenges and opportunities. *Asian Economic Journal*, *36*(4), 325–349.

Rotondi, Z., Stanca, L., & Tomaselli, V. (2020). Digital transformation and firm performance: Evidence from Indonesian SMEs. *Journal of Small Business Management*, *59*(6), 1221–1248.

Ruiu, M. L., & Ragnedda, M. (2024). *Digital-environmental poverty: Digital and environmental inequalities in the post-Covid era*. Cham: Springer Nature.

Sandee, H. (2015). Connectivity and infrastructure. *Asian Economic Policy Review*, *10*(1), 116–133.

Sen, A. (1999). *Development as freedom*. Oxford: Oxford University Press.

Sen, C. K. (2021). Human wound and its burden: Updated 2020 compendium of estimates. *Advances in Wound Care*, *10*(5), 281–292. https://doi.org/10.1089/wound.2021.0026

Silver, E. A., & Li, Y. (2025). Cross-national perspectives on mathematical problem posing. *Asian Journal for Mathematics Education*, *4*(2), 295-307. https://doi.org/10.1177/27527263251347663

Son, H. H. (2007). *Pro-poor growth: Concepts and measures (Technical Note Series)*. Manila, Philippines: Asian Development Bank.

Stiglitz, J. E. (2016). Inequality and economic growth. In M. Jacobs & M. Mazzucato (Eds.), Rethinking capitalism: Economics and policy for sustainable and inclusive growth. In (pp. 134–155). Chichester, UK: Wiley-Blackwell

Sugiarti, S., Yunianto, B., Damayanti, R. A., & Hadijah, N. R. (2021). Legalizing illegal small-scale mining is a policy of business guarantee and environmental management. *IOP Conference Series Earth and Environmental Science*, *882*(1), 12077. https://doi.org/10.1088/1755-1315/882/1/012077

Suryadarma, D., & Sumarto, S. (2013). Improving educational quality through enhancing community participation: Evidence from Indonesia. *Education Economics*, *21*(2), 1–22.

Tadesse, G., & Bahiigwa, G. (2015). Mobile phones and farmers' marketing decisions in Ethiopia. *World Development*, *68*, 296-307. https://doi.org/10.1016/j.worlddev.2014.12.010

Tonggiroh, M. (2017). *Digital government services in Papua*. Paper presented at the 2017 Second International Conference on Informatics and Computing (ICIC). IEEE.

UN ESCAP. (2020). *Asian and pacific training centre for information & communication technology for development (APCICT): Final evaluation report*. Bangkok, Thailand: UN ESCAP.

UNCTAD. (2021). *Digital economy report 2021: Cross-border data flows and development: For whom the data flow*. New York: United Nations.

Van Kesteren, M., Smith, J., & Lee, P. (2019). Economic growth and the limits of the trickle-down hypothesis. *Journal of Development Studies*, *55*(4), 567–582.

Vélez, M. A., Robalino, J., & Robles, M. (2022). Neighborhood effects and poverty dynamics in developing countries. *Journal of Development Economics*, *155*, 102781.

Weltbank. (2023). *World Bank East Asia and Pacific economic update, October 2023: Services for growth*. Washington, DC: World Bank Publications.

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data* (2nd ed.). Cambridge, MA: MIT Press.

World Bank. (2016). *Indonesia's urban story*. Washington, DC: World Bank Group.

World Bank. (2023a). *Indonesia poverty assessment: Pathways towards economic security. Official report with BPS data analysis*. Washington, DC: World Bank Group.

World Bank. (2023b). *Migrants, refugees, and societies. World Development Report 2023*. Washington, DC: World Bank Group.

World Bank. (2024). *Funding Indonesia's vision 2045* Washington, DC: World Bank Group.

World Health Organization (WHO). (2023). *Self-care interventions for sexual and reproductive health and rights to advance universal health coverage: 2023 joint statement by HRP, WHO, UNDP, UNFPA, and the World Bank*. Geneva: World Health Organization.

Yang, T.-C., Noah, A. J., & Shoff, C. (2015). Exploring geographic variation in US mortality rates using a spatial Durbin approach. *Population, Space and Place*, *21*(1), 18-37. https://doi.org/10.1002/psp.1809

Ye, Y., Chen, S., & Li, C. (2022). Financial technology as a driver of poverty alleviation in China: Evidence from an innovative regression approach. *Journal of Innovation & Knowledge*, *7*(1), 100164. https://doi.org/10.1016/j.jik.2022.100164

Yun, W. S. (2024). Quality growth in poverty reduction provinces in Indonesia. *EcceS: Economics, Social and Development Studies*, *11*(2), 166–190.

Zakaria, J. (2024). *Pro-poor development in Indonesia: Strategies for inclusive and high-quality growth*. Jakarta: Indonesian Development Policy Institute.

Zhang, X., & Xu, F. (2023). Environmental regulation and spatial spillover effect of green technology innovation: An empirical study on the spatial Durbin model. *Sustainability*, *15*(19), 14133. https://doi.org/10.3390/su151914133

Zhang, Y. F., & Zhao, H. (2025). The effect of e-commerce on digitally inclusive finance: Evidence from the e-commerce boom in rural China. *Cogent Economics & Finance*, *13*(1), 2460082. https://doi.org/10.1080/23322039.2025.2460082