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Connected But Unequal? The Heterogeneous Economic Returns To Broadband Infrastructure Expansion In Indonesia

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ABSTRACT

Background: Broadband infrastructure expansion has become a central strategy for promoting economic growth and reducing regional inequality; however, improvements in digital connectivity do not necessarily generate equitable economic benefits.
Objective: This study examines the heterogeneous economic returns of broadband infrastructure and identifies factors influencing productivity, income distribution, and regional development.
Method: A preliminary integrative literature synthesis was conducted using seven empirical publications from 2022–2024, applying comparative analysis and thematic categorization to identify recurring patterns and explanatory mechanisms.
Results: Three interconnected themes emerged: broadband connectivity and economic productivity, uneven digital dividends across regions, and the complementary roles of human capital and local productive capabilities.
Findings and Implications: The synthesis suggests that broadband expansion alone does not guarantee immediate economic growth or reduced inequality, as outcomes depend on productive technology utilization, socioeconomic conditions, and regional absorptive capacity. These findings emphasize the importance of combining infrastructure investment with digital literacy, enterprise development, and inclusive regional policies.
Conclusion: Equitable digital transformation requires coordinated technological, economic, and institutional interventions to translate connectivity improvements into sustainable and inclusive regional development.

INTRODUCTION

Digital infrastructure has become a fundamental component of contemporary economic development, reshaping how firms coordinate production, households access markets, and governments deliver public services across increasingly interconnected economies. The expansion of broadband networks is particularly consequential for developing countries because improved connectivity can reduce information asymmetries, lower transaction costs, and facilitate participation in digitally mediated economic activities. Empirical evidence indicates that internet connectivity is positively associated with international trade and

economic welfare, although the magnitude of these benefits varies across countries and institutional environments (Herman & Oliver, 2023). Nevertheless, the economic consequences of digitalization cannot be understood solely through aggregate connectivity indicators because technological access does not necessarily translate into equivalent productive capabilities across regions. Research examining European regions demonstrates that broadband expansion can accelerate economic growth while producing substantially different returns between urban and rural economies, depending on network characteristics and territorial conditions (de Clercq et al., 2023). These concerns are especially relevant to Indonesia, where geographical fragmentation, uneven infrastructure development, and substantial differences in regional economic capacity complicate the equitable distribution of digital opportunities. Evidence from Indonesian underdeveloped regions further suggests that broadband expansion may have nonlinear relationships with income inequality, reinforcing the importance of examining whether improved connectivity generates inclusive economic development rather than merely expanding technological coverage (Ariansyah et al., 2023).

The relationship between broadband infrastructure and regional economic performance can be understood through the complementary perspectives of general-purpose technology, endogenous growth, and absorptive capacity, which collectively emphasize that technological investments generate economic value through interactions with existing productive resources. Broadband networks constitute an enabling infrastructure because they facilitate information exchange, digital transactions, organizational coordination, and knowledge diffusion, although their economic returns depend on the extent to which firms and households can exploit these opportunities. Evidence from a quasi-natural experiment in China indicates that broadband infrastructure can improve firm productivity through mechanisms involving information development, resource allocation, innovation, and reduced transaction costs (Zhang et al., 2022). From an absorptive-capacity perspective, however, the benefits of technological infrastructure are conditional upon complementary investments in human capital, organizational capabilities, and institutional arrangements that support productive technology adoption. Cross-country evidence from developing economies highlights the importance of interactions between information and communication technologies and human capital when examining income distribution, suggesting that connectivity and educational capabilities should not be treated as independent determinants of development (Nga Ndjobo & Ngah Otabela, 2023). Moreover, research on regional broadband expansion demonstrates that economic returns differ according to connectivity quality and regional characteristics, challenging the assumption that infrastructure investment produces homogeneous productivity improvements across geographical areas (de Clercq et al., 2023). Consequently, broadband infrastructure should be conceptualized not merely as a physical network investment but as a potentially transformative economic resource whose developmental consequences depend on the interaction between technological availability and locally embedded capabilities.

Despite substantial public investment in digital connectivity, an unresolved empirical problem concerns whether broadband infrastructure expansion produces measurable improvements in regional economic performance and whether those improvements are distributed equitably across territories with different initial development conditions. This problem is particularly evident in Indonesia, where the Palapa Ring project was designed to strengthen national telecommunications connectivity and reduce geographical disparities in access to digital infrastructure. An empirical evaluation covering 46 Indonesian districts found that Palapa Ring infrastructure significantly improved internet connectivity but did not generate a statistically significant effect on regional gross domestic product during the observation period (Eschachasthi et al., 2022). Such findings challenge the conventional expectation that

improved telecommunications infrastructure automatically stimulates regional economic growth, although the absence of a statistically significant aggregate effect does not establish that all economic consequences are negligible. In contrast, evidence from European regions identifies positive relationships between broadband expansion and per capita economic growth, with substantial differences according to broadband speed and rural development characteristics (de Clercq et al., 2023). Indonesian evidence further indicates an inverted U-shaped association between mobile broadband coverage and income inequality, implying that the distributional consequences of connectivity may change as network coverage expands (Ariansyah et al., 2023). These contrasting findings reveal a fundamental analytical tension between improvements in digital access, aggregate economic outcomes, and distributional effects, thereby motivating a more differentiated assessment of how broadband infrastructure interacts with pre-existing regional development characteristics.

Investigating the heterogeneous economic consequences of broadband infrastructure is increasingly urgent because digital connectivity has become an essential input for business operations, public administration, education, financial services, and participation in emerging technology-intensive markets. For developing economies with pronounced territorial disparities, the effectiveness of infrastructure expenditure must be evaluated not only through improvements in network availability but also through its contribution to productive transformation and economically meaningful outcomes. Evidence from Indonesian underdeveloped regions suggests that the relationship between broadband expansion and inequality depends on the extent of network coverage, highlighting the possibility that early infrastructure improvements may initially benefit relatively advantaged economic participants (Ariansyah et al., 2023). Furthermore, research on information technology and adult literacy across developing countries emphasizes the importance of educational conditions in understanding the distributional implications of digital technologies (Asongu et al., 2024). These findings imply that infrastructure-oriented digital development strategies may require complementary policies addressing human capital, digital capabilities, and local productive structures if their economic benefits are to extend beyond already competitive regions. The Indonesian context is particularly relevant because existing evaluations of Palapa Ring identify improvements in connectivity without corresponding statistically significant regional output effects, raising questions about whether conventional aggregate indicators adequately capture the developmental consequences of infrastructure investment (Eschachasthi et al., 2022). Accordingly, a rigorous assessment of regional economic heterogeneity is necessary to inform infrastructure prioritization, improve the allocation of complementary public investments, and distinguish technological connectivity from the broader realization of inclusive economic development.

Recent empirical scholarship provides substantial evidence that broadband infrastructure can influence economic performance, although the direction, magnitude, and distribution of its effects remain sensitive to research design, geographical context, and outcome measurement. Using a quasi-natural experimental framework in China, Zhang et al. (2022) identified positive firm-level productivity effects associated with broadband infrastructure and discussed information development, resource reallocation, innovation, and transaction-cost reduction as plausible transmission mechanisms. However, firm-level productivity improvements do not necessarily imply equivalent increases in district-level economic output because regional aggregates also reflect sectoral composition, labor-market adjustment, and differences in firms' capacity to adopt digital technologies. In Indonesia, Eschachasthi et al. (2022) employed a staggered difference-in-differences framework to evaluate Palapa Ring infrastructure, documenting improved internet connectivity without statistically significant effects on regional gross domestic product. Although their analysis

incorporated heterogeneity and robustness assessments, its observation period ended in 2020, leaving subsequent adjustment dynamics and longer-run changes in local economic structures outside the evaluated period. Meanwhile, Ariansyah et al. (2023) examined 122 underdeveloped Indonesian regions and identified a nonlinear relationship between mobile broadband coverage and income inequality, thereby extending the discussion beyond average economic growth toward distributional consequences. Taken together, these studies suggest that a meaningful extension of the literature must distinguish infrastructure availability from economic utilization, evaluate multiple dimensions of regional economic performance, and investigate whether initial development conditions shape the temporal and structural distribution of broadband-related benefits.

Building on this evidence, the present study proposes a multidimensional examination of broadband infrastructure expansion that distinguishes changes in aggregate regional economic performance from changes in economic structure and differences in returns associated with pre-existing regional capabilities. Its potential contribution does not rest solely on identifying heterogeneous treatment effects, because previous Indonesian research has already examined heterogeneity in the economic consequences of Palapa Ring infrastructure (Eschachasthi et al., 2022). Instead, the study seeks to connect the possibility of weak aggregate output responses with sectoral restructuring and baseline human-capital conditions, thereby examining whether economic transformation may occur even when conventional growth indicators reveal limited immediate improvements. This analytical distinction is consistent with evidence that broadband-related productivity gains may operate through several firm-level mechanisms whose aggregate manifestations depend on local economic composition and complementary resources (Zhang et al., 2022). The proposed framework also responds to findings that digital infrastructure may exhibit nonlinear distributional relationships, while avoiding the assumption that differences in regional treatment effects necessarily constitute direct evidence of changes in income inequality (Ariansyah et al., 2023). Methodologically, the research intends to integrate district-level secondary economic indicators with independently verified infrastructure exposure and implementation timing, using a quasi-experimental framework only where the available evidence supports credible comparisons between treated and untreated regions. By jointly considering aggregate output, sectoral economic composition, and predetermined absorptive-capacity characteristics, the study aims to clarify the conditions under which expanded digital connectivity becomes economically productive and the circumstances in which infrastructure provision alone may be insufficient.

The novelty of this study lies in its integrative conceptual framework for explaining the heterogeneous economic returns of broadband infrastructure expansion by connecting digital connectivity, economic productivity, regional inequality, and absorptive capacity within a unified analytical perspective. Unlike previous studies that primarily examined broadband infrastructure in relation to individual economic indicators, such as regional economic growth, firm productivity, or income inequality (Eschachasthi et al., 2022; Zhang et al., 2022; Ariansyah et al., 2023), this research synthesizes these dimensions to explain why improvements in digital connectivity do not necessarily generate immediate, uniform, or equitable economic benefits. Specifically, the study distinguishes infrastructure availability from productive technology utilization and examines how human capital, institutional conditions, and regional economic structures may shape the distribution of digital economic opportunities. By integrating general-purpose technology theory, absorptive capacity, and regional development perspectives, the research proposes a multidimensional framework that connects technological access with economic transformation and distributional outcomes. Furthermore, the study contributes a context-sensitive interpretation of Indonesia's digital

development challenges, particularly the divergence between improved broadband connectivity and measurable regional economic performance. Its contribution is grounded in a preliminary synthesis of seven empirical studies rather than a completed systematic review or original causal estimation. Consequently, the proposed framework provides a theoretical foundation for future empirical investigations and offers policy insights into combining broadband infrastructure investment with digital literacy, human capital development, and locally appropriate productive capabilities to promote more inclusive and sustainable regional economic growth.

The primary objective of this study is to examine whether broadband infrastructure expansion is associated with changes in regional economic performance across Indonesian districts and to assess whether these changes differ according to initial levels of economic development and human capital. Specifically, the research seeks to evaluate changes in real gross regional domestic product per capita, investigate potential shifts in sectoral economic composition, and determine whether pre-existing regional characteristics systematically condition the observed economic responses. Where reliable infrastructure implementation dates and appropriate comparison regions can be established, the study will employ a quasi-experimental panel-data strategy to estimate differential economic responses while assessing pre-treatment trends, dynamic adjustment patterns, and relevant identification assumptions. The anticipated theoretical contribution lies in connecting the economic role of general-purpose digital infrastructure with absorptive-capacity arguments and regional structural transformation, thereby developing a more integrated explanation of geographically uneven digital development. Empirically, the study is expected to provide a transparent and reproducible assessment of broadband-related economic outcomes using publicly accessible Indonesian regional statistics and documented infrastructure information, without presupposing the direction or statistical significance of the eventual findings. From a policy perspective, the analysis may help identify whether telecommunications infrastructure investments should be accompanied by targeted improvements in education, digital skills, and local productive capabilities to enhance their potential economic returns. Ultimately, the research aims to advance a more conditional understanding of digital infrastructure and regional development, emphasizing that the achievement of inclusive economic benefits depends not only on extending network connectivity but also on enabling geographically diverse communities to transform technological access into sustainable productive opportunities.

METHOD

This study employs a systematic literature review with an integrative thematic synthesis approach to investigate the heterogeneous economic consequences of broadband infrastructure expansion in Indonesia and comparable developing economies. The systematic review design is appropriate because the relationship between digital connectivity, regional economic growth, structural transformation, and socioeconomic inequality has been examined using diverse theoretical perspectives, geographical units, and empirical identification strategies, making structured evidence synthesis necessary to identify convergent findings and unresolved inconsistencies. Unlike a conventional narrative review, the proposed approach establishes explicit procedures for literature identification, eligibility assessment, methodological appraisal, data extraction, and cross-study comparison, thereby improving transparency and reproducibility. The review will follow the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) reporting framework, which provides a standardized structure for documenting search procedures, screening decisions, and evidence inclusion (Page et al., 2021). To accommodate differences between experimental, quasi-experimental,

longitudinal, and observational studies, the synthesis will integrate methodological appraisal with thematic comparison rather than assume that heterogeneous effect estimates can be meaningfully combined in a single statistical model. This design is further supported by contemporary methodological guidance emphasizing that systematic reviews should explicitly connect their research questions, eligibility criteria, and synthesis methods to the characteristics of the available evidence (Higgins et al., 2024). Accordingly, the review will evaluate how broadband infrastructure influences regional economic performance, whether these effects differ across socioeconomic contexts, and which institutional or human-capital conditions appear to shape the distribution of digital economic benefits.

Data Sources and Search Strategy

The literature search will cover Scopus, Web of Science Core Collection, ScienceDirect, SpringerLink, and Google Scholar, with Scopus and Web of Science serving as the primary bibliographic databases and the remaining platforms providing supplementary discovery and citation-tracing opportunities. Searches will focus on publications from January 2021 through October 2026 to capture recent evidence on broadband expansion, digital infrastructure, economic growth, regional development, and inequality, while earlier foundational studies may be retained solely for theoretical contextualization. The search strategy will combine controlled conceptual categories and free-text terms using Boolean operators, with the principal search expression formulated as ("broadband infrastructure" OR "internet connectivity" OR "digital infrastructure" OR "broadband expansion" OR "Palapa Ring") AND ("economic growth" OR "regional development" OR "economic productivity" OR "structural transformation" OR "income inequality") AND ("Indonesia" OR "developing countries" OR "emerging economies"). Database-specific syntax, field restrictions, and truncation rules will be adapted to each platform, with title, abstract, and keyword searches prioritized where supported. Searches will initially be restricted to English-language peer-reviewed journal articles and scholarly conference proceedings, while Indonesian-language publications will be considered when they provide directly relevant empirical evidence concerning national broadband policies or district-level development outcomes. Backward reference screening and forward citation tracking will supplement electronic database searches to identify relevant studies that may not be retrieved through the initial keyword combinations. Search dates, database interfaces, query strings, applied filters, and retrieved record counts will be documented in accordance with PRISMA-S guidance to facilitate transparent reporting and subsequent replication (Rethlefsen et al., 2021).

Inclusion and Exclusion Criteria

Studies will be eligible for inclusion when they examine broadband or digital connectivity infrastructure in relation to measurable economic outcomes, including regional output, productivity, employment, structural transformation, income distribution, or socioeconomic disparities, and provide sufficient methodological information to support critical appraisal. Eligible empirical studies may employ randomized or quasi-experimental designs, difference-in-differences estimation, instrumental-variable approaches, panel regression, spatial econometrics, or other clearly specified quantitative methods, while mixed-methods studies will be included when their quantitative or qualitative findings directly address the review questions. Studies focusing exclusively on technical network performance, telecommunications engineering, digital literacy without economic outcomes, or general technology adoption unrelated to infrastructure expansion will be excluded, as will editorials, opinion pieces, duplicate publications, and records without sufficient accessible

methodological information. The screening process will proceed through record identification, duplicate removal, title and abstract screening, full-text eligibility assessment, and final study inclusion, with reasons for full-text exclusion documented in a PRISMA 2020 flow diagram (Page et al., 2021). Bibliographic records will be organized using Zotero or equivalent reference-management software, and duplicate detection will combine automated bibliographic matching with manual verification of titles, authors, publication years, and digital object identifiers. Methodological quality will be assessed using design-appropriate appraisal criteria addressing sampling and measurement validity, treatment assignment, confounding, temporal ordering, model specification, statistical inference, and transparency of reported findings, with particular attention to the limitations of causal claims derived from observational infrastructure data. Consistent with contemporary guidance on risk-of-bias assessment, studies will not be excluded solely because their findings are statistically insignificant; instead, methodological limitations and the credibility of identification assumptions will inform the interpretation and relative evidential weight assigned during synthesis (Higgins et al., 2024).

Data Extraction and Synthesis Procedures

Data extraction will be conducted using a standardized coding matrix developed in Microsoft Excel or R, recording bibliographic characteristics, country and geographical coverage, observation periods, analytical units, infrastructure indicators, economic outcome measures, research designs, estimation methods, principal findings, and reported limitations. Additional fields will capture potential moderating factors, including baseline income, educational attainment, urbanization, industrial composition, institutional quality, and digital adoption capacity, allowing the review to examine whether differences in economic outcomes correspond to differences in pre-existing regional capabilities. The extracted evidence will first be summarized descriptively according to publication year, geographical setting, methodological approach, and outcome category, after which a structured thematic synthesis will identify recurring patterns concerning connectivity improvements, productivity responses, regional structural change, and unequal economic returns. Thematic categories will be developed through iterative comparison between theoretically informed concepts and empirically reported findings, with the analytical process documented to distinguish directly observed results from interpretations advanced by the reviewers. Where sufficient comparable effect estimates and variance measures are available, a quantitative synthesis may be considered; however, substantial variation in infrastructure interventions, geographical units, outcome definitions, and identification strategies would favor structured narrative synthesis over an inappropriate pooled estimate. R will be used for descriptive tabulations, reproducible data processing, and graphical summaries, while VOSviewer may be employed for supplementary bibliometric visualization if the final corpus contains enough bibliographic records to support meaningful network analysis. The synthesis will follow the principles of transparent narrative reporting described by Campbell et al. (2020), while maintaining a clear distinction between the direction of reported associations, the strength of causal identification, and the extent to which findings can be generalized to Indonesian regional development.

Reliability, Validity, and Ethical Considerations

Reliability and methodological trustworthiness will be strengthened through a predefined review protocol, standardized eligibility criteria, transparent coding definitions, and systematic documentation of decisions made throughout the literature identification and synthesis processes. Ideally, two independent reviewers will screen titles, abstracts, and full texts and independently code a subset of eligible studies, with disagreements resolved through discussion or adjudication by a third reviewer; if only one reviewer is available, this limitation

will be explicitly disclosed rather than presenting unperformed independent assessments as completed procedures. Inter-reviewer agreement may be evaluated using Cohen's kappa or percentage agreement, while coding consistency will be examined through repeated extraction of a sample of studies and comparison of the resulting records. Methodological triangulation will involve comparing findings across different research designs, economic indicators, geographical settings, and infrastructure measures to determine whether apparent contradictions arise from substantive contextual differences or variations in analytical credibility. The review will distinguish between statistically significant associations and well-identified causal effects, with sensitivity assessments considering the influence of study quality, geographical scope, publication type, and alternative outcome definitions. Ethical standards will be maintained through accurate attribution, verification of bibliographic metadata, preservation of original authors' interpretations, and explicit reporting of uncertainties, consistent with recommendations for transparent systematic review reporting (Page et al., 2021). Because the research relies exclusively on publicly available scholarly publications and does not involve direct collection of identifiable personal information, formal human-participant ethics approval is generally not required, although applicable institutional research-integrity and data-management policies will remain binding..

RESULTS AND DISCUSSION

The preliminary evidence set comprises seven studies published between 2022 and 2024, selected from the publications identified during the preceding development of the manuscript rather than through a completed systematic database search. These publications address broadband infrastructure, digital connectivity, economic productivity, regional development, and income distribution across Indonesian, Chinese, European, and broader developing-country contexts. The evidence includes quasi-experimental studies, longitudinal regional analyses, cross-country investigations, and observational studies of economic and distributional outcomes. The diversity of analytical approaches provides a foundation for identifying recurring mechanisms, although it limits the comparability of effect estimates and prevents an immediate quantitative meta-analysis. Table 1 summarizes the principal characteristics of the preliminary evidence set, distinguishing reported empirical findings from the broader interpretations developed in this discussion. Figure 1 illustrates the current evidence identification and selection status, explicitly identifying procedures that remain incomplete rather than presenting hypothetical screening counts as actual research results. Accordingly, the following analysis should be understood as a structured preliminary synthesis that identifies plausible research themes and testable propositions rather than a definitive systematic review.

The reviewed literature suggests three interconnected analytical themes concerning the economic consequences of broadband infrastructure expansion. The first concerns the relationship between technological connectivity and measurable economic productivity, particularly the possibility that improved network access does not immediately generate proportional changes in aggregate economic output. The second concerns the uneven distribution of digital economic opportunities across regions, firms, and socioeconomic groups with different initial capabilities. The third examines the complementary role of human capital, institutional conditions, and productive structures in determining whether infrastructure investments translate into sustained economic transformation. Graph 1 presents the publication-year distribution of the provisional evidence set, providing a descriptive overview of its temporal concentration without implying that the distribution represents the wider literature. The concentration of selected publications in the early part of the review window

highlights the need for additional systematic searches covering more recent studies before finalizing the evidence base. These themes collectively provide an organizing framework for evaluating how broadband expansion may simultaneously improve technological access, produce differentiated economic outcomes, and interact with existing development inequalities.

Table 1. Characteristics of the Preliminary Evidence Set

Study	Context	Method or focus	Principal finding or contribution
Eschachasthi et al. (2022)	Indonesia, 46 districts	Staggered difference-in-differences	Improved connectivity, without a statistically significant GRDP effect
Zhang et al. (2022)	China, firms	Quasi-natural experiment, DID	Positive firm productivity effects through several economic mechanisms
Ariansyah et al. (2023)	Indonesia, 122 underdeveloped regions	Panel regression	Inverted U-shaped relationship between broadband coverage and income inequality
de Clercq et al. (2023)	European regions	Regional economic analysis	Broadband growth relationships vary across urban and rural contexts
Herman and Oliver (2023)	International	Digital trade and economic development	Examines connectivity-related trade and welfare relationships
Nga Ndjobo and Ngah Otabela (2023)	Developing countries	ICT–human capital interaction analysis	Examines interactions between ICT, human capital, and inequality
Asongu et al. (2024)	Developing countries	ICT, inequality, and literacy analysis	Examines the role of literacy in digital development outcomes

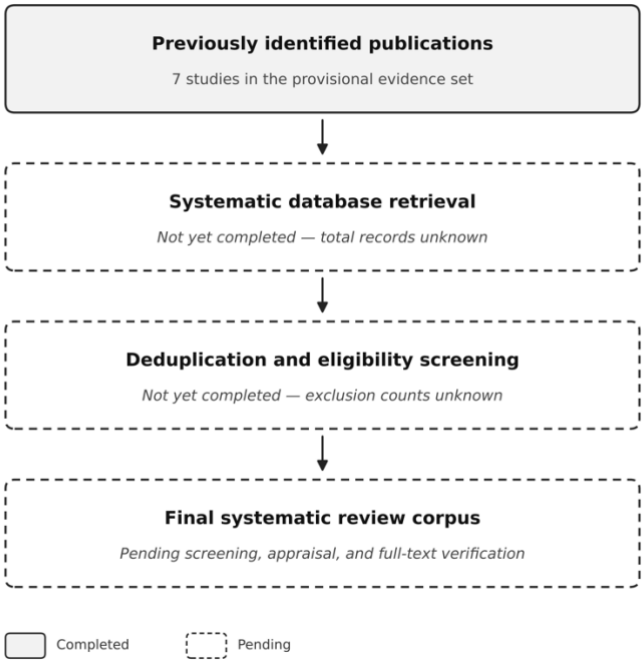


Figure 1. Current Status of Evidence Identification and Selection

Broadband Connectivity, Economic Productivity, and the Infrastructure–Growth Disconnect

The first thematic finding concerns the distinction between expanding broadband connectivity and generating measurable economic productivity improvements. Across the provisional evidence set, infrastructure availability emerges as an enabling condition for economic activity rather than a sufficient determinant of growth. The Indonesian evaluation by Eschachasthi et al. (2022) illustrates this distinction by reporting a statistically significant improvement in internet connectivity following Palapa Ring infrastructure development without identifying a statistically significant effect on regional gross domestic product. This divergence is analytically important because it challenges interpretations that treat telecommunications infrastructure expenditure as an immediate indicator of economic development success. Improvements in network availability may initially affect communication opportunities, information access, and transaction processes without producing sufficiently large changes in recorded regional production. Moreover, aggregate economic indicators may conceal adjustments occurring within individual firms, households, or economic sectors, particularly when gains are concentrated in activities representing a relatively small proportion of regional output. The evidence therefore supports distinguishing the technological outputs of infrastructure investment from its intermediate behavioral effects and ultimate economic outcomes.

Evidence from China provides a contrasting perspective by identifying measurable productivity improvements associated with broadband infrastructure expansion. Zhang et al. (2022) employed a quasi-natural experimental approach based on the Broadband China policy and reported positive effects on firm-level total factor productivity. Their analysis identified improvements in information development, resource allocation, innovation, and transaction costs as plausible mechanisms connecting infrastructure investment with productive efficiency. These mechanisms suggest that broadband can generate economic benefits when firms possess organizational processes capable of converting improved connectivity into operational

changes. However, firm-level productivity gains should not be interpreted as direct evidence that equivalent improvements will emerge in aggregate regional output, because the two outcomes represent different levels of economic organization. The contrast with Eschachasthi et al. (2022) consequently raises questions concerning the geographical concentration of productive firms, the diffusion of digital technologies, and the capacity of local economies to absorb technological improvements. Rather than establishing contradictory causal relationships, these studies suggest that the observed effects of broadband expansion depend partly on the outcome being measured and the economic unit receiving the infrastructure intervention.

A further dimension of this relationship concerns the temporal process through which connectivity improvements become economically productive. Telecommunications infrastructure may be installed relatively quickly, whereas organizational adaptation, workforce training, digital service development, and market integration can require considerably longer periods. The Indonesian Palapa Ring evaluation covered 2015–2020, making its findings particularly relevant to the initial implementation period but less informative about subsequent economic adjustment (Eschachasthi et al., 2022). By comparison, the Chinese firm-level evidence demonstrates that broadband infrastructure can be associated with measurable productivity improvements when the empirical setting captures firms' responses to a policy intervention (Zhang et al., 2022). These differences support a hypothesis of temporally uneven returns, although the available studies do not establish a common adjustment period or demonstrate that delayed gains necessarily emerge. It is also possible that certain infrastructure investments fail to generate substantial economic returns because complementary market institutions, digital capabilities, or business opportunities remain inadequate. Consequently, future empirical evaluations should distinguish short-run connectivity effects, intermediate changes in economic behavior, and longer-run productivity responses without assuming that all three stages will occur automatically.

The broader theoretical implication is that broadband infrastructure should be evaluated as part of a system of complementary productive assets rather than as an isolated technological input. Evidence from European regions suggests that broadband-related growth relationships vary across geographical environments, reinforcing the importance of local economic conditions when interpreting infrastructure outcomes (de Clercq et al., 2023). Similarly, Zhang et al. (2022) identified stronger productivity responses among particular categories of Chinese firms, indicating that organizational characteristics may condition the economic value of connectivity. These findings are compatible with a general-purpose technology perspective in which the productive contribution of infrastructure depends on complementary investments, institutional adaptation, and opportunities for technological recombination. Nevertheless, the available evidence does not permit the conclusion that any specific complementary factor universally determines broadband-related economic performance. For the Indonesian context, this uncertainty highlights the value of examining sectoral economic composition alongside aggregate regional output, since the effects of digital connectivity may be more visible in particular productive activities than in total GRDP. The synthesis thus identifies a research opportunity to investigate whether weak aggregate growth responses coexist with measurable structural changes, while recognizing that this proposition requires direct empirical testing.

Regional Inequality, Uneven Digital Dividends, and Nonlinear Economic Returns

The second thematic finding concerns the uneven distribution of broadband-related economic opportunities across territories and socioeconomic groups. Improved digital connectivity may expand access to information and markets while simultaneously allowing already advantaged individuals, firms, or regions to capture a disproportionate share of the

resulting economic benefits. Ariansyah et al. (2023) provide directly relevant Indonesian evidence through an analysis of 122 underdeveloped regions between 2018 and 2021. Their study identified an inverted U-shaped relationship between mobile broadband coverage and income inequality, indicating that inequality initially increased with expanding coverage before the estimated relationship became favorable at higher coverage levels. The reported turning point occurred at approximately 60 percent coverage of the population area, although this estimate is specific to the study's measurement framework and sample. Such findings challenge the assumption that digital infrastructure expansion necessarily produces immediate distributional improvements across all stages of technological diffusion. Instead, they suggest that the developmental consequences of connectivity may depend on the maturity of network deployment and the extent to which previously excluded economic participants gain meaningful access.

The nonlinear relationship identified in Indonesian underdeveloped regions provides an important basis for distinguishing digital inclusion from economic equality. During the initial stages of broadband expansion, better-resourced households and firms may be positioned to exploit connectivity because they already possess suitable devices, relevant skills, financial resources, and market relationships. Under these conditions, expanding network coverage could increase the relative advantages of digitally prepared participants even as average technological access improves. Ariansyah et al. (2023) provide empirical support for a nonlinear coverage–inequality relationship, although their estimates do not directly establish the individual behavioral mechanisms responsible for the observed pattern. The interpretation is consistent with the broader proposition that information and communication technologies interact with existing socioeconomic conditions rather than operating independently of them. Research examining ICT and human-capital interactions in developing countries further indicates that the distributional implications of digital technologies warrant analysis alongside educational capabilities (Nga Ndjobo & Ngah Otabela, 2023). Accordingly, the relationship between broadband infrastructure and inclusive development should be examined through the interaction of network availability, effective utilization, and the socioeconomic resources required to transform connectivity into economic participation.

Geographical heterogeneity adds another dimension to the distributional consequences of digital infrastructure investment. Regional economies differ in population density, industrial specialization, transportation access, market proximity, and the availability of skilled labor, creating substantial variation in their capacity to benefit from improved telecommunications networks. Research on European regions identifies differences in broadband-related growth relationships between urban and rural settings, suggesting that network characteristics and territorial conditions influence economic outcomes (de Clercq et al., 2023). Meanwhile, the Indonesian evidence on mobile broadband and inequality indicates that the consequences of connectivity expansion may change across different stages of infrastructure coverage (Ariansyah et al., 2023). Although these studies examine different outcomes and geographical contexts, their findings collectively challenge the expectation of uniform economic returns from similar categories of digital investment. The distinction is especially important for archipelagic economies because infrastructure provision may address physical connectivity constraints without eliminating disparities in human capital, productive resources, and market accessibility. Therefore, regional heterogeneity should be treated as a central analytical dimension of digital development rather than a secondary statistical consideration introduced only after estimating average infrastructure effects.

The relationship between broadband expansion and inequality also requires careful differentiation between economic growth disparities and income distribution outcomes. A

region experiencing relatively strong GRDP growth following infrastructure development does not necessarily exhibit reduced household income inequality, because aggregate production gains may accrue unevenly across sectors, firms, and workers. Conversely, improvements in digital inclusion may support household welfare without immediately producing substantial changes in measured regional output. The findings of Ariansyah et al. (2023) concern income inequality, whereas Eschachasthi et al. (2022) examine connectivity and regional economic activity, making their outcome measures analytically related but not interchangeable. Combining these perspectives reveals a limitation in studies that infer inclusive development solely from aggregate economic growth or infrastructure coverage indicators. A more comprehensive evaluation would examine whether infrastructure-related economic changes are accompanied by improvements in labor-market participation, household income opportunities, or other directly observed distributional outcomes. This synthesis therefore supports a multidimensional research agenda while emphasizing that regional differences in estimated growth effects should not be presented as direct evidence of changes in income inequality.

Human Capital, Institutional Complementarities, and Regional Structural Transformation

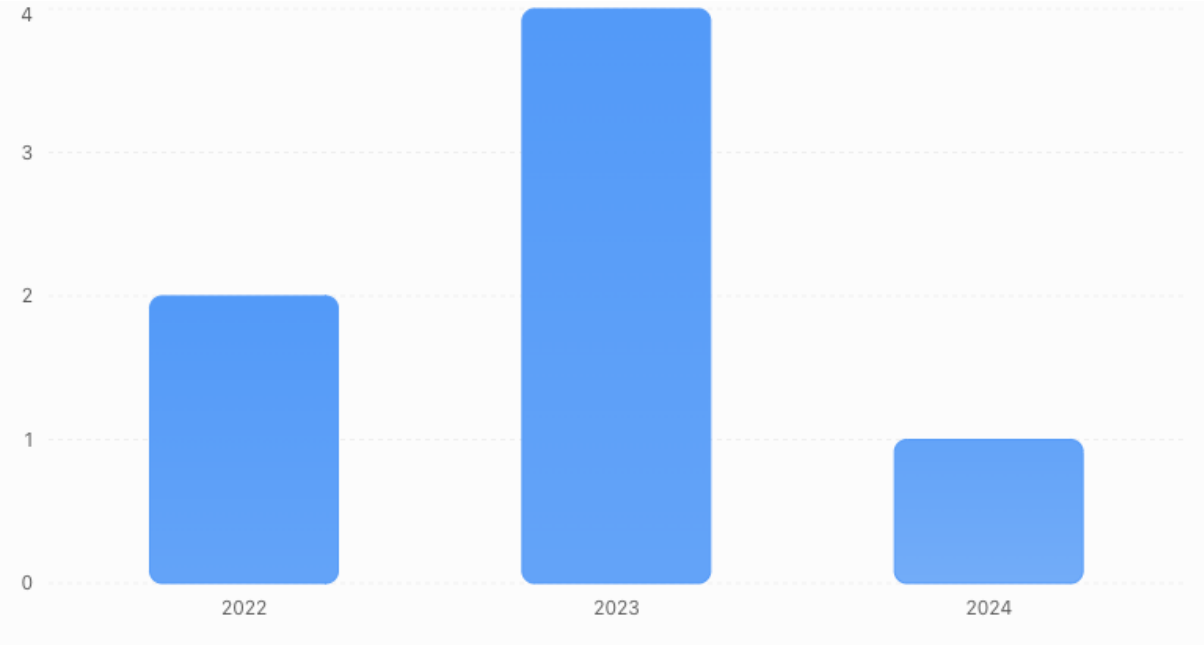
The third thematic finding concerns the role of complementary capabilities in determining whether improved broadband connectivity becomes a source of sustainable economic development. The theoretical significance of these capabilities follows from the observation that technological infrastructure expands potential opportunities but does not guarantee their effective utilization. Human capital is particularly relevant because education, digital literacy, and occupational skills influence how individuals and organizations acquire, interpret, and apply digitally transmitted information. Nga Ndjobo and Ngah Otabela (2023) examined interactions between information and communication technologies and human capital in relation to income inequality across developing countries, highlighting the analytical importance of considering technological and educational conditions together. Research by Asongu et al. (2024) similarly situates information technology, inequality, and adult literacy within a common development framework. These contributions suggest that the economic and distributional consequences of connectivity should be interpreted in relation to the capabilities of potential technology users rather than infrastructure availability alone. Consequently, human capital represents a theoretically relevant conditioning factor in the relationship between broadband expansion and regional economic performance, although the direction and magnitude of that interaction require context-specific empirical estimation.

Institutional and organizational complementarities provide a second explanation for variation in broadband-related economic outcomes. Even when network coverage improves, firms may be unable to exploit digital opportunities if they lack managerial capabilities, financing, technological equipment, or effective market connections. Zhang et al. (2022) identified several plausible productivity mechanisms, including improved information processing, innovation, and resource allocation, which require organizational decisions beyond the physical installation of telecommunications infrastructure. These mechanisms imply that the economic benefits of broadband expansion may be influenced by the quality of business environments and the ability of firms to reorganize productive activities. However, the available evidence does not establish that all institutional conditions exert equivalent moderating effects across industries or geographical settings. The Indonesian Palapa Ring findings demonstrate the practical importance of this distinction because connectivity improvements were not accompanied by statistically significant aggregate GRDP effects during the evaluated period (Eschachasthi et al., 2022). Taken together, the evidence motivates a complementary-assets interpretation in which infrastructure effectiveness depends on the

interaction between technological access, organizational readiness, and locally available economic opportunities.

Structural transformation constitutes a third potential mechanism through which broadband infrastructure may influence regional development. Digital connectivity can alter the relative attractiveness of economic activities by facilitating electronic commerce, remote services, information-intensive production, and coordination across geographically dispersed markets. These opportunities may encourage changes in sectoral composition even when aggregate regional output responds slowly or remains statistically indistinguishable from its counterfactual trajectory. The productivity mechanisms identified by Zhang et al. (2022) provide a theoretical basis for expecting changes in resource allocation and innovation, although their study does not directly establish sectoral transformation within Indonesian districts. Similarly, Eschachasthi et al. (2022) assessed regional economic activity through GRDP but did not establish whether infrastructure exposure produced offsetting changes across different economic sectors. This distinction suggests that aggregate output measures may be insufficient for identifying the full range of adjustments associated with digital infrastructure expansion. Nevertheless, sectoral restructuring remains a proposed analytical mechanism rather than an established result of the present review, and its empirical relevance must be tested using consistent sector-level economic indicators.

The combined evidence points toward a conditional model of broadband-related structural development in which the productive consequences of connectivity depend on existing regional capabilities. Regions with stronger human capital and diversified economic activities may possess greater opportunities to integrate broadband into production, whereas regions with weaker complementary resources may experience improvements in access without equivalent economic gains. The interaction between ICT and human capital examined by Nga Ndjobo and Ngah Otabela (2023) provides a relevant theoretical foundation for this interpretation. Meanwhile, the nonlinear distributional relationship reported by Ariansyah et al. (2023) suggests that the socioeconomic consequences of connectivity may evolve as infrastructure coverage becomes more extensive. These findings are compatible with a cumulative-advantage mechanism, although the reviewed studies do not collectively establish that broadband expansion inevitably increases regional disparities. Graph 1 also demonstrates that the provisional evidence set is concentrated in 2022–2024, reinforcing the need to incorporate newer studies before drawing definitive conclusions about contemporary digital infrastructure outcomes. The central contribution of this thematic synthesis is therefore the identification of complementary capabilities and economic structure as linked dimensions requiring joint evaluation in future Indonesian broadband research.



Graph 1. **Publication-Year Distribution of the Provisional Evidence Set**

Cross-Theme Integration

The three thematic findings converge on the proposition that digital infrastructure development involves a sequence of potentially distinct technological, behavioral, productive, and distributional processes. Improved broadband availability may increase connectivity, but the translation of this technological improvement into economic performance depends on whether households and firms possess the capabilities and incentives required for productive utilization. The first theme establishes that connectivity gains and aggregate productivity outcomes can diverge, while the second demonstrates that economic opportunities associated with digital expansion may be distributed unevenly across socioeconomic contexts. The third theme provides a theoretical explanation for these differences by emphasizing the complementary roles of human capital, organizational readiness, and local economic structure. Interconnectedly, the findings suggest that the relationship between broadband infrastructure and economic development is neither necessarily immediate nor uniformly positive across all dimensions of welfare. This interpretation provides a basis for integrating general-purpose technology theory with absorptive-capacity arguments and regional development perspectives without claiming that the available evidence establishes a universal causal sequence. The resulting framework treats broadband infrastructure as an enabling condition whose economic consequences are mediated by productive utilization and conditioned by existing regional capabilities.

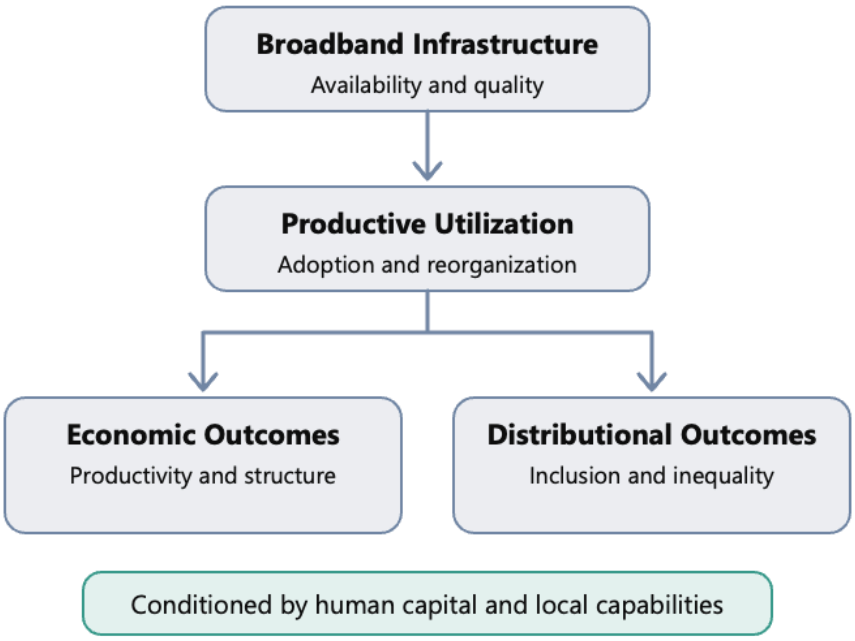


Figure 2. Proposed Integrated Framework of Broadband-Related Economic Development

The integrated framework in Figure 2 distinguishes infrastructure availability from productive utilization and separates economic outcomes from distributional consequences. Its central proposition is that improved connectivity influences development through intermediate processes involving technology adoption, organizational adaptation, information exchange, and resource allocation. Human capital and regional economic capabilities are represented as conditioning factors because they may influence both the utilization of digital infrastructure and the distribution of resulting benefits. This framework offers a way to interpret the apparent divergence between positive firm-level productivity findings and statistically insignificant aggregate output responses without assuming that either result is methodologically invalid. It also accommodates nonlinear inequality relationships by recognizing that the distribution of benefits may change as connectivity becomes more widespread and economic participation broadens. Nevertheless, the proposed framework remains conceptual because the present evidence set does not provide harmonized estimates capable of testing its complete causal structure. Future empirical research should therefore evaluate its components separately and jointly, using clearly defined treatment measures, credible comparison groups, and economic outcomes that distinguish growth from distribution.

Practical Implications and Research Limitations

The synthesis suggests that public investment strategies should evaluate broadband infrastructure through economic utilization and distributional outcomes rather than network construction indicators alone. For Indonesian policymakers, this implies that infrastructure planning may benefit from coordinated investments in digital literacy, workforce capabilities, business support services, and locally relevant digital applications. Regions with limited productive capacity may require complementary interventions that enable households and enterprises to convert improved connectivity into economically meaningful activities. Educational institutions and vocational training providers can contribute by developing digital competencies aligned with regional employment structures and the technological needs of local businesses. Telecommunications operators and technology developers may likewise improve infrastructure effectiveness by supporting service affordability, reliable network performance,

and practical applications for smaller enterprises. However, these recommendations should be interpreted as policy implications derived from the comparative literature rather than interventions whose effectiveness has been directly established by the present review. Their implementation should be accompanied by monitoring frameworks that separately assess network quality, technology utilization, economic performance, and distributional inclusion.

Several limitations constrain the strength and generalizability of the present synthesis. Most importantly, the seven publications constitute a preliminary evidence set rather than the output of a completed systematic search, meaning that the analysis cannot establish comprehensive coverage of relevant research. The concentration of publications in 2022–2024, illustrated in Graph 1, may omit more recent empirical findings and methodological developments that could modify the interpretations presented here. Differences in geographical scale, infrastructure definitions, outcome measures, and econometric strategies also limit direct comparability across the selected studies. In addition, several mechanisms discussed in the thematic analysis are theoretically plausible interpretations rather than causal pathways independently verified across all reviewed contexts. The absence of completed risk-of-bias assessments, independent screening, and standardized effect-size extraction further prevents definitive judgments about the overall strength of the evidence. Consequently, the conclusions should be regarded as provisional and should not be represented as the findings of a fully completed PRISMA-compliant systematic review.

Future research should prioritize a completed systematic review with comprehensive database searches, transparent screening procedures, and formal methodological quality appraisal. Where studies report sufficiently comparable outcomes and effect estimates, meta-analytic techniques could help determine whether broadband-related economic effects vary systematically by infrastructure type, geographical context, or baseline development conditions. Additional quasi-experimental investigations using Indonesian district-level data would be particularly valuable for evaluating whether broadband rollout produces delayed changes in economic output and sectoral composition. Such studies should distinguish verified service activation from infrastructure construction and incorporate appropriate methods for addressing endogenous placement, spatial spillovers, and heterogeneous treatment effects. Cross-country comparisons could further clarify whether the relationships identified in Indonesian underdeveloped regions are consistent with those observed in other emerging economies. Research combining administrative economic indicators with measures of actual broadband utilization would also help identify the mechanisms through which technological access becomes productive economic activity. These directions would advance a more rigorous understanding of digital infrastructure as a conditional development resource while providing stronger empirical foundations for policies seeking both economic growth and equitable participation in the digital economy.

CONCLUSION

The persistent gap between expanding broadband connectivity and achieving equitable economic development highlights the need to understand why digital infrastructure investments generate heterogeneous economic outcomes across regions. Addressing this problem through a preliminary synthesis of empirical literature, this study identifies three interconnected dimensions shaping broadband-related development: economic productivity, distributional inequality, and the complementary roles of human capital and regional productive capabilities. The synthesis indicates that improvements in technological connectivity do not necessarily translate into immediate aggregate economic growth, while the distribution of potential benefits may vary according to infrastructure coverage, socioeconomic conditions, and local absorptive capacity. The study contributes theoretically by integrating

general-purpose technology, absorptive capacity, and regional development perspectives into a conceptual framework that distinguishes infrastructure availability, productive utilization, and economic distribution, while methodologically emphasizing the importance of multidimensional outcome assessment. Consequently, the research advances a conditional understanding of digital infrastructure development, suggesting that the economic value of broadband expansion depends not only on network accessibility but also on the capacity of regional economies to transform technological opportunities into productive and inclusive outcomes.

Based on these insights, policymakers should complement broadband infrastructure expansion with targeted investments in digital literacy, workforce development, affordable connectivity, and support mechanisms that strengthen the technological capabilities of enterprises in economically disadvantaged regions. Infrastructure evaluation frameworks should incorporate indicators of productive technology utilization, sectoral economic transformation, and distributional outcomes alongside conventional measures of network coverage and regional economic growth. Nevertheless, the study is limited by its preliminary evidence base of seven publications, the absence of a completed systematic screening and methodological quality assessment, and differences in geographical contexts, research designs, and economic indicators that constrain the generalizability of its interpretations. Future research should therefore undertake comprehensive systematic reviews, investigate comparable economic effects through rigorous quasi-experimental designs, and examine the dynamic relationships among broadband adoption, human capital, structural transformation, and regional inequality using longitudinal data. Ultimately, advancing equitable digital development requires an integrated approach that combines technological investment with complementary economic and institutional capabilities, thereby enabling policymakers and researchers to move beyond connectivity expansion toward a more comprehensive understanding of sustainable and inclusive economic transformation.

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CONFLICT OF INTEREST

The authors declare that this research was conducted in the absence of any commercial, financial, or personal relationships that could be construed as potential conflicts of interest. The authors further confirm that no competing interests influenced the research design, data interpretation, manuscript preparation, or publication of this study.

AUTHOR CONTRIBUTIONS

[Author 1] and [Author 2] contributed to the information technology aspects of the study, including the conceptualization of broadband infrastructure, digital connectivity, technological frameworks, and the interpretation of technology-related findings. [Author 3] and [Author 4] were responsible for the economic aspects of the research, including the examination of regional economic development, economic productivity, income inequality, and the socioeconomic implications of digital infrastructure expansion. [Author 5] contributed to manuscript proofreading, academic language editing, grammatical accuracy, and the improvement of linguistic clarity, coherence, and overall readability. All

authors contributed to the manuscript development within their respective areas of expertise, critically reviewed the intellectual content, and approved the final version for publication.

GENERATIVE AI STATEMENT

The authors declare that generative artificial intelligence (AI) tools were used during the preparation of this manuscript. Specifically, ChatGPT (OpenAI) was utilized to assist with preliminary manuscript drafting, language refinement, and the organization of academic content; Claude (Anthropic) was employed to assist in generating and developing visual illustrations and figures; and Grammarly was used to improve grammatical accuracy, spelling, punctuation, and overall linguistic clarity. The use of these tools was limited to supporting the manuscript preparation process and did not replace the authors' independent intellectual contributions, scholarly judgment, or responsibility for the research. All authors were responsible for critically reviewing, revising, proofreading, and validating the AI-assisted content, including verifying the accuracy of research data, methodological descriptions, analytical interpretations, citations, references, and visual materials. The authors affirm that all scientific arguments, conclusions, and interpretations presented in the manuscript remain their intellectual responsibility and that AI-generated outputs were not accepted without appropriate human evaluation and verification. The use of generative AI was conducted in accordance with applicable ethical principles, academic integrity standards, and the journal's policies concerning transparency and responsible AI-assisted scholarly writing. The authors assume full accountability for the originality, accuracy, integrity, and final published content of this manuscript.

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