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Trade Complexity and Growth under the Indonesia-Australia Partnership

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ABSTRACT

Research Originality: This study contributes by linking Indonesia-Australia bilateral trade, economic complexity, and wholesale price dynamics within a single error-correction framework following the partnership's entry into force.

Research Objectives: The study investigates the impact of exports, imports, economic complexity, merchandise trade openness, and wholesale prices on Indonesia's growth in both the short and long term from 2010 to 2025.

Research Methods: Annual data are analyzed using Augmented Dickey-Fuller tests, Engle-Granger cointegration tests, and an error correction model, supported by residual diagnostics, for five bilateral trade variables.

Empirical Results: The results indicate that all variables are associated with long-term development, while wholesale prices, imports, and exports primarily drive short-term fluctuations. Economic complexity is more significant as a structural channel than as an annual upheaval.

Implications: These results suggest that Indonesia should focus on trade liberalization under the IA-CEPA, as it could serve as a real growth engine. Policy should move beyond trade volume targets by enhancing export diversification, stabilizing wholesale price transmission, and leveraging the partnership to strengthen skills, technology transfer, and higher-value-added production.

Keywords:

bilateral partnership; economic complexity; export sophistication; error correction model; trade liberalization

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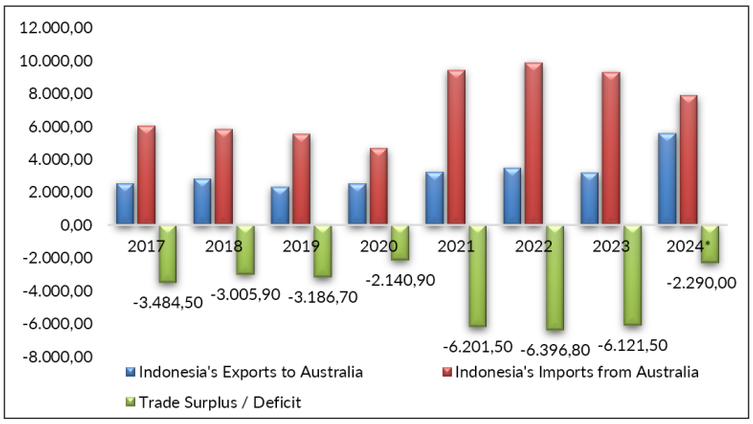
INTRODUCTION

Indonesia and Australia signed the Indonesia-Australia Comprehensive Economic Partnership Agreement in July 2020 after lengthy discussions and identified one of the most vibrant trade corridors in the Indo-Pacific (Shaommy & Paksi, 2024). The accord is intended to enhance market access, remove trade barriers, and encourage co-operation on investment, skills, services, and regional value chains. The contract is important for Indonesia because Australia is a nearby market that has not been tapped historically. Indonesia is an important and growing economy for Australia, with rising demand for food, education, resources, services, and manufacturing inputs (Toledo, 2017). Indonesia has always adopted an outward-oriented development strategy to boost the economy.

Recent figures suggest that bilateral trade has grown since the pact, but the distribution of benefits remains uneven. Exports from Indonesia to Australia improved compared to 2019, the pre-agreement year, but Indonesia still had a trade imbalance, as imports from Australia exceeded exports. This condition makes the agreement analytically interesting. The policy concern is not just whether trade increases following liberalization, but also whether the structure of trade can promote long-term growth in Indonesia.

Figure 1. The Value of Indonesia–Australia Merchandise Trade Before and After the Implementation of the IA-CEPA



(Source: Hansa, 2024).

Based on Figure 1, Indonesia's exports to Australia have generally increased since 2019, following the entry into force of the IA-CEPA. However, Indonesia still faces a trade deficit because the value of imports from Australia exceeds that of its exports. The deepest deficit occurred between 2021 and 2023, primarily due to a surge in imports from Australia. Consequently, following ratification, numerous analyses have been conducted to assess the impact of bilateral trade between Indonesia and Australia from various sources.

The agreement aims to boost trade and investment, foster bilateral and regional economic integration, and provide a strong basis for cooperation in security, environmental protection, economic cooperation, education, cross-border concerns, and people-to-people relations. The IA-CEPA eliminates customs duties and improves Indonesia's exports to

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Australia across several sectors, including automotive, timber, rubber, textiles, electronics, machinery, food and drink, and the creative industries. Furthermore, human resource development initiatives, such as internships and vocational training, are tailored to the needs of the Indonesian industry. The agreement adopts an opportunity-driven approach in a business-friendly environment (Wibisono, 2025), ensuring active involvement of business actors from the outset. Previous studies on Indonesia's trade agreements generally emphasize market access, foreign direct investment, sectoral adjustment, exchange-rate effects, or trade volume. Narayan et al. (2022) show that trade agreements can support investment in Indonesia, while Noureen & Mahmood (2022) and Rahman et al. (2024) highlight the role of trade costs, uncertainty, and exchange-rate asymmetry in bilateral trade. Studies on IA-CEPA have also discussed market access and sectoral opportunities, including specific factors adjustment and green economy cooperation. However, this literature has paid less attention to the joint role of trade volume, economic complexity, and domestic wholesale price transmission in explaining Indonesia's macroeconomic growth after IA-CEPA.

The research gap is therefore threefold. First, earlier assessments rarely cover the post-normalization period after the initial pandemic shock. A study by Verma (2026) focused on bilateral agreements, using variables such as trade volume, computable general equilibrium models, and panel data prior to the pandemic shock. Second, most studies focus on export and import values but do not explicitly test whether the sophistication of the export basket matters for growth. Moreover, limited attention has been given to the structural quality of trade, especially the role of economic complexity in shaping long-run growth outcomes. A study by Rahim & Sudirman (2023) also noted that while focusing solely on trade volume is important, quality also plays a crucial role, as the traded commodities enhance the competitiveness of that trade. Third, price transmission through wholesale prices is usually treated as background macroeconomic information rather than as part of the trade-growth mechanism. These omissions are important because trade agreements can affect growth through fast demand channels, slow structural channels, and price-level channels (Bhattacharyay & Mukhopadhyay, 2015).

The ECI measures the productive knowledge embedded in a country's export basket (Hidalgo & Hausmann, 2009). Even less, incorporate the Wholesale Price Index (WPI) to capture the transmission of inflation through bilateral channels. The study by Muthahharah et al. (2025) emphasizes the use of the WPI as a benchmark for measuring economic stability in ongoing bilateral trade. Another study from Anggresta et al. (2024) aimed to identify the determinants of foreign debt that influence economic growth in Indonesia. Although not directly related to trade and macroeconomic stability, this study can also contribute to understanding the impact of debt fluctuations on the balance of payments.

This gap is important because trade agreements affect growth through several mechanisms that operate at different temporal frequencies. Volume effects occur on a relatively short time horizon; structural transformation through economic complexity occurs over years or decades; and price-level adjustments are transmitted continually via import and export channels. Similarly, the role of intangible costs in international trade can be understood as part of the broader trade picture, rather than being addressed solely

in terms of volume (Linders et al., 2005). The originality of this work lies in integrating bilateral exports, bilateral imports, economic complexity, merchandise trade openness, and wholesale prices into a single error-correction model for Indonesia for the period 2010-2025. This design allows the study to distinguish short-run trade shocks from long-run structural transformation. The study jointly models ECI and WPI alongside export and import quantities within a unified ECM framework to disentangle structural from macroeconomic effects, a methodological advancement over prior studies that examined trade volumes or structural indicators in isolation.

The objective goal is to estimate the speed of adjustment to long-run equilibrium after deviations from trade policy changes or external shocks indicated by the error correction term (ECT). The results are discussed in light of the recent empirical conversations on trade, complexity, and development, and also attempts to examine the role of trade variables, as does the study by (Gürel & Ergül, 2026; Kim, 2026), which tries to investigate and explain the effects of real exchange rate movements on a country's bilateral trade using various approaches. Lastly, the study has three objectives: to estimate the short-run and long-run effects of these variables on Indonesia's real GDP growth; to measure the speed of adjustment toward long-run equilibrium; and to derive policy recommendations for maximizing the growth benefits of the Indonesia-Australia partnerships.

METHODS

Annual data are used because key variables such as real GDP growth, economic complexity, and merchandise trade share are officially and consistently reported at annual frequency. Constructing biannual or quarterly observations would require interpolation for some variables and could introduce artificial variation. The study uses time series data for the period 2010-2025. The primary methodological enhancement relative to the base study (2010-2023) is the extension through 2025. The modest sample size (N = 16 observations) is typical of ECM-based studies of specific bilateral linkages (Akbar et al., 2025; Narayan, 2005). The sample contains 16 annual observations. The model is intentionally parsimonious and adheres to the Engle-Granger two-step error-correction approach, thereby mitigating this limitation. The primary objective in small samples is to determine whether the variables exhibit a stable long-term relationship and to prevent over-parameterization. Shrestha & Bhatta (2018) provide supporting arguments when working with time series data, economists encounter the challenge of selecting a method. Common methods used to analyze other categories of data may not be appropriate for time series data, which may exhibit specific properties such as trends and structural breaks.

In a small sample of 16 annual observations, including seasonally noisy quarterly data would inflate residual variance, reduce the power of ADF unit root tests, and risk spurious regression results. The parsimonious ECM framework is specifically designed for low-frequency data where the signal-to-noise ratio is maximized. Finally, IA-CEPA is designed to produce macroeconomic effects over multi-year horizons, not within single quarters. Structural transformation, as captured by ECI, unfolds over years or decades, making an annual frequency both empirically appropriate and policy-relevant. Moreover,

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with only five post-ratification years (2020–2025), quarterly data would yield only 20 observations, which is insufficient for the Engle-Granger two-step procedure, which requires a sufficient number of observations to estimate both the long-run cointegrating equation and short-run dynamics.

Table 1. Dependent and Independent Variables

Variable	Symbol	Definition	Unit	Source / Year
GDP Growth Rate	GDP	Real GDP growth rate of Indonesia	% (Percentage)	World Bank / IMF WEO 2025
Export Value	EX	Indonesian merchandise exports to Australia	USD billion	Trade Map / DFAT 2025
Import Value	IM	Indonesian merchandise imports from Australia	USD billion	Trade Map / DFAT 2025
Economic Complexity Index	ECI	Hidalgo-Hausmann ECI of Indonesia's export basket	Index value	OEC World 2025
Merchandise Trade Share	MT	Total merchandise trade as % of Indonesia's GDP	% of GDP	World Bank 2025
Wholesale Price Index	WPI	Indonesia's domestic wholesale price level	Index (base yr)	BPS / World Bank 2025

The ECM is suitable when macroeconomic variables are individually non-stationary but share a common stochastic trend (i.e., are cointegrated). Unlike a VAR in first differences, ECM keeps the long-run information in the cointegrating vector and models short-run adjustment dynamics as well (Engle & Granger, 1987). Such a dual structure is well-suited to examining the response of Indonesian GDP to deviations from its long-run trade-determined equilibrium path, the key question for this article. The ECM also overcomes the small sample problem by using a parsimonious specification to reduce over-parameterization. Following the Engle-Granger two-step procedure, the long-run cointegrating equation is approximated by OLS:

$$GDP_t = \beta_0 + \beta_1 EX_t + \beta_2 IM_t + \beta_3 ECI_t + \beta_4 MT_t + \beta_5 WPI_t + \varepsilon_t \quad (1)$$

If the residuals ε_t are stationary $[I(0)]$ Cointegration is confirmed. The short-run ECM is:

$$\Delta GDP_t = \alpha_0 + \alpha_1 \Delta EX_t + \alpha_2 \Delta IM_t + \alpha_3 \Delta ECI_t + \alpha_4 \Delta MT_t + \alpha_5 \Delta WPI_t + \alpha_6 \Delta ECT_{t-1} + \mu_t \quad (2)$$

where Δ is the first-difference operator and ECT_{t-1} is the lagged residual from equation (1). The coefficient α_6 captures the speed of adjustment towards long-run equilibrium; its expected sign is negative. We estimate pre-estimation for every variable in levels and initial differences; we perform Augmented Dickey-Fuller (ADF) unit root tests, with the lag length determined by the Schwarz Information Criterion. Cointegration is tested using the Engle-Granger residual-based ADF test. Also, we add post-estimation as four diagnostic checks are employed to assess the adequacy of the model, namely, the Jarque-Bera test for residual normality, the White test for heteroscedasticity, the Breusch-Godfrey LM test for autocorrelation (up to lag 2), and variance inflation factors (VIF) to detect deleterious multicollinearity.

RESULTS AND DISCUSSION

The results provide three principal findings. The long-run model indicates that bilateral trade, economic complexity, merchandise trade openness, and wholesale prices are correlated with Indonesia's growth. Secondly, the short-run model shows that annual growth variations are primarily driven by fluctuations in exports, imports, and wholesale prices. The negative and significant error correction term indicates that deviations from the long-term trajectory are promptly rectified. These results show that IA-CEPA provides a platform for growth but does not promise automatic growth. The longer-term payoff depends on Indonesia's ability to translate trade access into advanced manufacturing capabilities.

The Augmented Dickey-Fuller tests conducted before model estimation confirm that the variables are non-stationary in levels and stationary in first differences. This lends support to cointegration and error correction modeling.

Table 3. Unit Root Test Results at Levels

Variable	ADF Stat.	CV (1%)	CV (5%)	CV (10%)	Prob.	Decision
GDP	−2.667	−4.122	−3.145	−2.714	0.1076	Non-stationary
EX	−0.444	−4.122	−3.145	−2.714	0.8714	Non-stationary
IM	−2.690	−4.122	−3.145	−2.714	0.1039	Non-stationary
ECI	−0.376	−4.122	−3.145	−2.714	0.8846	Non-stationary
MT	−1.161	−4.297	−3.213	−2.748	0.6451	Non-stationary
WPI	−1.327	−4.122	−3.145	−2.714	0.5803	Non-stationary

The results show that none of the six variables rejects the null hypothesis of a unit root at any conventional level of significance. This indicates that all series are non-stationary in levels (see Table 3). This is not surprising because annual macroeconomic data, such as GDP growth rates, price indices, and trade flows, often exhibit stochastic properties that must be filtered out before reliable statistical relationships can be discerned. All six series are stationary after the first difference. The five variables (ΔGDP, ΔEX, ΔIM, ΔECI, ΔWPI) reject the unit root null hypothesis at 5% significance level. ΔMT reaches a stable state at the 10% significance level. This marginal significance is characteristic of small-sample time series: Narayan (2005) particularly advocates the 10% ADF criterion as suitable for samples of 15–25 annual observations, where degrees of freedom and not true non-stationarity constrain statistical power.

Table 4. Unit Root Test Results at First Difference

Variable	ADF Stat.	CV (1%)	CV (5%)	CV (10%)	Prob.	Decision
ΔGDP	−3.991	−4.297	−3.213	−2.748	0.0157	Stationary I (1)
ΔEX	−4.041	−4.200	−3.175	−2.729	0.0128	Stationary I (1)
ΔIM	−4.528	−4.200	−3.175	−2.729	0.0061	Stationary I (1)
ΔECI	−4.033	−4.297	−3.213	−2.748	0.0147	Stationary I (1)
ΔMT	−3.207	−4.297	−3.213	−2.748	0.0504	Stationary I (1)
ΔWPI	−3.483	−4.200	−3.175	−2.729	0.0308	Stationary I (1)

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The Engle-Granger cointegration test was conducted on the residuals of the long-run OLS regression, and it was found that all variables were I(1). Moreover, the Engle-Granger residual test indicates a stable long-run relationship among the variables. That is, the variables do not move together by chance but share a long-run equilibrium relationship that can be evaluated economically.

Table 5. Engle-Granger Cointegration Test on OLS Residuals

Series Tested	ADF Stat.	MK CV (1%)	MK CV (5%)	MK CV (10%)	Prob.	Decision
ECT (Residuals)	−3.825	−4.122	−3.145	−2.714	0.0163	Stationary – Cointegrated

Table 6. Long-run OLS Cointegration Results

Variable	Coefficient (β)	Std. Error
Constant (C)	−10.938**	4.194
Exports (EX)	0.188*	0.084
Imports (IM)	1.151**	0.833
ECI	3.968*	0.578
Merchandise Trade (MT)	0.411**	0.129
Wholesale Price Index (WPI)	0.071**	0.025
Adjusted R^2	0.584	
F-Statistic	4.366**	
Durbin-Watson	2.056	

Notes: ** significant at 5% *significant at 10%

Table 6 presents the long-run OLS cointegration model estimating the steady-state link between Indonesia's GDP growth and the five bilateral trade and structural factors. The long-term findings indicate that trade liberalization fosters growth when accompanied by structural enhancement. The coefficient for economic complexity is the highest among the variables, indicating that the composition and sophistication of exports are more significant than trade volume alone. This finding aligns with contemporary research on economic complexity, which posits that growth is contingent on productive skills, knowledge acquisition, and the capacity to transition to more advanced activities. This aligns well with a parsimonious bilateral trade model, as macroeconomic development is influenced by factors beyond bilateral trade flows, including domestic investment, government expenditure, commodity price fluctuations, and global financial conditions.

Both exports and imports exhibit favorable long-term correlations with economic growth. Exports are significant due to demand, foreign exchange revenues, and economies of scale. Imports are significant, as numerous items from Australia, such as food, raw materials, and intermediate inputs, bolster production and help maintain price stability in Indonesia. This interpretation diverges from a mere deficit narrative. A trade deficit may coexist with growth impacts when imports enhance production capacity, yet it also indicates a necessity for improved Indonesian export competitiveness.

Table 7. Short-run ECM Results

Variable	Coefficient (α)	Std. Error
Constant (C)	−0.024	0.446
ΔExports (ΔEX)	0.113**	0.077
ΔImports (ΔIM)	0.680**	0.610
ΔECI	20.373	12.661
ΔMerchandise Trade (ΔMT)	0.249	0.148
ΔWPI	0.074***	0.015
ECT (−1)	−1.413**	0.451
Adjusted R^2	0.785	
F-Statistic	7.706**	
Durbin-Watson	2.155	

Note: *** significant at 1%, ** significant at 5%

Table 7 shows the short-run ECM results. The short-term results are more selective. Economic complexity and trade openness are not statistically significant; variations in yearly growth are correlated with variations in exports, imports, and wholesale pricing. This is a good economic pattern." Output can be affected within a year by export and import dynamics and by the demand for and availability of inputs. Wholesale prices can change quickly due to supply conditions, import costs, and domestic demand. Economic complexity involves education, investment, skill upgrading, technological integration, and institutional coordination, and thus operates over a longer time horizon.

Table 8. Post-Estimation Diagnostic Test Results

Test	Test Statistic	Probability	Decision
Normality (Jarque-Bera)	1.831	0.400	Normally distributed
Heteroscedasticity (White)	Obs·R^2 = 2.456	0.873	No heteroscedasticity
Autocorrelation (Breusch-Godfrey)	Obs·R^2 = 3.134	0.209	No autocorrelation
Multicollinearity (Max VIF)	VIF = 2.613	–	No harmful multicollinearity

The error correction term is negative and statistically significant, implying that the system returns to its long-run equilibrium after a disruption. The size gives you the sense that it settles fast and might overshoot. This should be taken with a grain of salt since the period of the IA-CEPA overlaps with the COVID-19 crisis and the recovery. The result doesn't mean IA-CEPA was the only catalyst for the revival. Rather, it suggests that trade-related factors and growth return to their long-run relationship quickly after a large shock. Han et al. (2026) drew a clear line between the 'announcement impacts' of trade treaties that can quickly alter expectations and investment decisions, and the 'structural implications' that take years to unfold as institutions and industry adjust. In the observation, it is not a failure of the model that ECI and MT are relevant in the long run but not in the short run, but rather an empirically expected aspect of structural trade policy.

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Table 8 reports the post-estimation diagnostic tests of the ECM. The diagnostic tests indicate that the model is appropriate. The residuals are normally distributed, and there is no evidence of heteroscedasticity or serial correlation. The maximum variance inflation factor is below the usual threshold for harmful multicollinearity. The results are especially important because the study was based on a small annual sample. The findings are mostly consistent with other studies on the indirect effects of trade agreements on growth through investment, trade costs, decrease of uncertainty, and structural upgrading (Wong & Chan, 2003). In line with the IA-CEPA study from Gray et al. (2022)The MT-WPI link is somewhat more stable than in the pre-agreement baseline, consistent with the trade facilitation provisions of the agreement, which flatten import cost structures and narrow the transaction-cost gap between border pricing and domestic wholesale markets. Meanwhile, the disruption was evident in all the major bilateral commercial relationships in the region (Furtana, 2025).

The trajectory of the Wholesale Price Index (WPI) offers further elucidation of the correlation among bilateral trade, price dynamics, and economic growth. The WPI rose from an index value of 104 in 2010 to a peak of 202 in 2024, then declined slightly in 2025. This pattern indicates that Indonesia's domestic wholesale prices were affected by both internal demand conditions and external trade pressures, including commodity price fluctuations, import costs, and supply chain disruptions. The correlation between merchandise trade share (MT) and WPI is thus economically significant. This finding aligns with Muthahharah et al. (2025), who underscore the significance of WPI as a measure of economic stability, and with Pastpipatkul et al. (2020), who demonstrate that trade openness and bilateral trade flows may influence price fluctuations in the Thailand–Japan context.

IA-CEPA affects Indonesia's economy through multiple channels, as evidenced by empirical results from a long-run OLS cointegration model, short-run ECM estimation, and descriptive analyses of MT and WPI. Bilateral trade flows have a favorable effect on Indonesia's long-run GDP growth. Export revenues have an aggregate demand effect. Imports from Australia may improve productivity by providing raw materials, food inputs, capital goods, and intermediate products. This confirms the dominant assumption in trade-growth literature that bilateral trade agreements promote growth through transaction costs, market access, and efficiency in resource allocation.

Since the IA-CEPA, Indonesia has sustained its annual economic growth at around 5.0% through 2025 despite the COVID-19 pandemic, commodity price volatility, and high global interest rates. This path is consistent with the argument that IA-CEPA provides trade stability and market-access assurance, as articulated by Park (2025) and Wibisono (2025). However, the findings suggest that trade liberalization should not be viewed merely as a strategy for volume increase.

The model shows that the strongest long-run connection is with the Economic Complexity Index (ECI), indicating that export sophistication is more important than export volume for long-term growth. The findings are consistent with Narayan et al. (2022) who emphasize the significance of trade agreements in shaping investment and structural improvement, and Calì et al. (2026) who emphasize the role of trade policy in enhancing exporter resilience.

The short-term results also support this idea. Changes in exports, imports, and WPI significantly affect annual GDP growth, whereas changes in ECI and MT do not in the near run. There are two reasons this lag time matters. The ECM framework is used first because trade volume shocks and price changes are immediate, whereas structural reforms take longer to respond. The second gives a realistic policy analysis of IA-CEPA. The immediate benefits of the agreement are evident in increased trade volumes and price volatility, but the more substantive developmental benefits depend on Indonesia's ability to diversify its export basket, strengthen industrial linkages, and move towards higher-value-added manufacturing. The results suggesting that research on trade agreements should focus not only on the volume of goods traded between countries but also on the types of goods traded and the influence of price transmission on the local economy.

CONCLUSION

This research contributes to the literature by giving empirical evidence on the macroeconomic consequences of IA-CEPA. The research objectives are achieved by establishing that Indonesia's growth is connected with Indonesia-Australia bilateral trade indicators on various time frames. Long-run GDP growth is linked to exports, imports, economic complexity, openness of commercial trade, and wholesale prices. In the long run, the most important factor is economic complexity, reflecting the reality that the quality and sophistication of output matter more than the volume of commerce. In the near term, the changes in growth are mostly tied to exports, imports, and wholesale prices. The negative error-correction term implies that the model converges to a long-run equilibrium after shocks. The magnitude should be read carefully since the pandemic corresponded with the early IA-CEPA period. Future research should employ a panel ECM across multiple ASEAN economies and incorporate structural break tests to separate the treaty's effects from those of other simultaneous shocks. Trade flows should be analyzed at the sectoral level. The model should be re-estimated when data for 2026-2027 become available to determine whether the current ECI increase above zero will yield a rising growth dividend.

The policy recommendation is to shift from a volume-based trade strategy to a capability-based trade strategy. Indonesia could leverage the cooperation to increase export sophistication, promote compliance with standards, facilitate technology transfer, and link training programs with companies that export higher-value-added commodities. Price stability also counts because wholesale prices are quite important in both time frames. Future research should include sectoral data, compare Indonesia with other partner nations, and test for structural breaks when longer post-agreement data become available.

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Macroeconomic Determinants of Economic Growth in Developing-8 Countries: Panel Cross-Sectionally Augmented ARDL

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ABSTRACT

Research Originality: This research is original in its examination of the impact of macroeconomic determinants on economic growth in Developing-8 countries, which accounts for cross-sectional dependence and country heterogeneity.

Research Objectives: The study aims to analyze the short-run and long-run effects of external debt, exchange rates, foreign direct investment, inflation, and balance of trade on economic growth in selected Developing-8 countries over the period 1997–2024.

Research Methods: The study employs a Cross-Sectionally Augmented ARDL model combined with the Error Correction Model, using secondary panel data from six Developing-8 countries to capture dynamic relationships and long-run equilibrium, supported by unit root, cross-sectional dependence, and robustness tests.

Empirical Results: The findings indicate that external debt and exchange rates have positive short-run effects on growth, while inflation and the trade balance have negative immediate effects. Foreign domestic investment shows no significant short-run effect but becomes positive in the long run, and the error correction term confirms a stable long-run relationship.

Implications: The results suggest that policymakers should ensure sustainable external debt management, maintain exchange rate stability, enhance the effectiveness of foreign domestic investment, and control inflation to support long-term economic growth in Developing-8 countries.

Keywords:
gross domestic product growth; external debt; exchange rates; inflation; balance of trade

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INTRODUCTION

The Developing-8, comprising Bangladesh, Egypt, Indonesia, Iran, Malaysia, Nigeria, Pakistan, and Türkiye, was established to strengthen economic cooperation and development. However, economic growth performance has varied considerably among members. Bangladesh recorded relatively stable growth, while Türkiye experienced greater volatility. Egypt and Indonesia showed moderate yet resilient growth, whereas Nigeria and Pakistan experienced recurrent economic fluctuations (Ibrahim et al., 2022; Otieno Jabuya et al., 2023). Economic growth remains a key policy objective in Developing-8 countries, as sustainable growth is essential for addressing structural challenges and enhancing economic resilience (Muhsin et al., 2024; Sajid et al., 2025). These challenges became more apparent during periods of financial instability, commodity price fluctuations, and the COVID-19 pandemic, highlighting differences in economic resilience across member countries (Zhu et al., 2025).

Numerous recent studies have sought to identify the macroeconomic factors driving economic growth in developing economies. Some studies emphasize the importance of foreign direct investment (FDI) as a source of capital accumulation, technology transfer, and productivity enhancement (Ayenew, 2022; Ullah et al., 2022; Vo & Ho, 2025). Other studies highlight the role of trade performance in promoting economic growth by increasing market access and enhancing allocative efficiency (Abendin & Duan, 2021; Kinfack & Bonga-Bonga, 2023; Jabuya et al., 2023). At the same time, macroeconomic stability indicators such as inflation and exchange rates have been found to significantly influence investment decisions, resource allocation, and overall economic performance (Chen et al., 2025; Ibrahim et al., 2022; Iqbal et al., 2024; Yeboah, 2025). In addition, external debt remains an important source of development financing for many developing countries, although excessive accumulation of debt may hinder growth by increasing fiscal burdens and macroeconomic vulnerability (Ayana et al., 2023; Dawood et al., 2021; Gaies & Nabi, 2021; Luu et al., 2024).

Previous studies provide mixed evidence on the determinants of economic growth. FDI has been found to promote economic growth through capital accumulation and productivity enhancement (Ayenew, 2022), while external financial inflows contribute positively to inclusive economic development (Afolabi Ibikunle et al., 2023). Conversely, excessive external debt may hinder economic growth by increasing fiscal burdens and debt-servicing obligations (Ayana et al., 2023; Mohamed & Bile Mohamud, 2025). Inflation has also been shown to adversely affect economic growth beyond certain threshold levels by increasing uncertainty and reducing investment incentives (Ibrahim et al., 2022; Khan, 2022). Likewise, exchange rate volatility can undermine economic performance by discouraging trade and investment activities (Buthelezi, 2023; Yilmazkuday, 2025). Although these studies provide valuable insights, their findings remain mixed and highly dependent on regional, institutional, and macroeconomic conditions.

Despite the extensive literature on the determinants of economic growth, empirical evidence for the Developing-8 countries remains limited. Most previous studies focus

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on specific regions such as Sub-Saharan Africa, ASEAN, or Latin America, while studies on Developing-8 economies are relatively scarce. Furthermore, existing research often examines external debt, foreign direct investment, inflation, exchange rates, and trade separately rather than within an integrated framework. In addition, many studies rely on conventional panel estimation techniques that do not adequately address cross-sectional dependence and heterogeneity across countries. These limitations create a research gap in understanding the short-run and long-run effects of key macroeconomic determinants on economic growth in the Developing-8 countries.

Despite the extensive literature on the determinants of economic growth, several gaps remain. First, previous studies have produced inconsistent findings regarding the effects of external debt, foreign direct investment, inflation, exchange rates, and trade performance on economic growth, suggesting that these relationships are highly context-specific and sensitive to differences in institutional and macroeconomic environments. Second, most existing studies focus on individual countries or broader regional groupings. In contrast, empirical evidence on Developing-8 (D-8) countries remains limited despite their growing economic significance and increasing integration within the global economy. Third, many previous studies rely on conventional panel estimation techniques that assume cross-sectional independence and parameter homogeneity, which can lead to biased and inconsistent estimates when countries are exposed to common external shocks and exhibit heterogeneous economic structures. To address these gaps, this study examines the effects of external debt, foreign direct investment, inflation, exchange rates, and balance of trade on economic growth in Developing-8 countries over the period 1997–2024. Specifically, the study investigates both the short-run and long-run relationships among these variables while accounting for country-specific heterogeneity and cross-country interdependence.

The novelty of this research lies in the application of a panel Cross-Sectionally Augmented Autoregressive Distributed Lag (ARDL) model, integrated with an Error Correction Model (ECM), to analyze the determinants of economic growth in the Developing-8 countries. Unlike previous studies, this approach simultaneously addresses cross-sectional dependence, heterogeneous country dynamics, and mixed orders of integration while estimating both short-run and long-run effects within a unified framework. By focusing on the relatively underexplored D-8 economies and employing a more robust econometric methodology, this study provides more comprehensive evidence on the macroeconomic determinants of economic growth. It offers policy-relevant insights for promoting sustainable economic development.

METHODS

This study employs secondary quantitative data obtained from the World Bank's World Development Indicators database. The population of this study comprises all member countries of the Developing-8 organization. However, the final sample comprises six countries: Bangladesh, Egypt, Indonesia, Nigeria, Pakistan, and Türkiye. Two Developing-8 member countries were excluded due to incomplete observations on

one or more variables during the study period, which could lead to an unbalanced panel and reduce the reliability of the estimated results. The analysis uses annual data from 1997 to 2024. Table 1 presents the operational definitions and measurement indicators for all variables used in this research.

Table 1. Operational Variables

Variables	Definitions	Measurements	References
Economic Growth (EG)	The increase in the value of goods and services produced within an economy	annual GDP growth (%)	(Gómez & Irewole, 2024; Srivastava et al., 2025; Yeboah, 2025)
External Debt (ED)	the total outstanding debt owed to foreign creditors, including public and private borrowing, IMF credit, and short-term debt	total external debt stocks (US$)	(Ayana et al., 2023; Dawood et al., 2021; Mohamed & Bile Mohamud, 2025)
Exchange Rate (ER)	The average value of the local currency compared to the US$	ratio (local currency per US$)	(Bhat et al., 2024; Ramos-Herrera, 2024; Yilmazkuday, 2025)
Foreign Direct Investment (FDI)	cross-border investment that grants investors significant influence or control over enterprises in another country	net foreign direct investment (US$)	(Ayenew, 2022; Choi & Kim, 2024; Mejia, 2023)
Inflation (INF)	The annual rate of change in the overall price level of an economy	annual GDP deflator (%)	(Chu, 2022; Ibrahim et al., 2022; Khan, 2022)
Balance of Trade (BOT)	The difference between the value of exports and imports of goods and services	net trade (US$)	(Abendin & Duan, 2021; Kinfack & Bonga-Bonga, 2023; Jabuya et al., 2023)

To examine the dynamic relationship between macroeconomic variables and economic growth, this study applies the panel ARDL model, which is appropriate because it accommodates variables integrated of order I(0) and I(1), allows simultaneous estimation of short-run and long-run relationships, and permits heterogeneity across cross-sectional units. The general panel ARDL model can be expressed as:

$$Y_{it} = \alpha_i + \sum_{j=1}^{p} \phi_j \, Y_{i,t-j} + \sum_{j=0}^{q} \beta_j \, X_{i,t-j} + \varepsilon_{it} \quad (1)$$

where Y_{it} denotes the dependent variable for the country i at time t, α_i represents country-specific effects, and ε_{it} is the disturbance term. The inclusion of lagged dependent variables captures the dynamic adjustment process inherent in economic growth behavior.

Given the presence of cross-sectional dependence, the baseline model is extended to the Cross-Sectionally Augmented ARDL model, which incorporates cross-sectional averages of the dependent and independent variables to account for unobserved common factors and reduce estimation bias (Jabuya et al., 2023). The panel Cross-Sectionally Augmented ARDL model can be expressed as:

$$Y_{it} = \alpha_i + \sum_{j=1}^{p} \phi_j \, Y_{i,t-j} + \sum_{j=0}^{q} \beta_j \, X_{i,t-j} + \sum_{j=0}^{p} \delta_j \, \bar{Y}_{t-j} + \sum_{j=0}^{q} \theta_j \, \bar{X}_{t-j} + \varepsilon_{it} \quad (2)$$

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An important advantage of the panel Cross-Sectionally Augmented ARDL model is its reparameterization into an Error Correction Model, which enables a clear separation between short-run dynamics and long-run equilibrium relationships. This formulation facilitates the identification of both adjustment processes and long-run coefficients. The ECM representation is given as:

$$\Delta Y_{it} = \alpha_i + \sum_{j=1}^{p-1} \phi_j' \, \Delta Y_{i,t-j} + \sum_{j=0}^{q-1} \beta_j' \, \Delta X_{i,t-j} + \sum_{j=0}^{p-1} \delta'_j \, \Delta \bar{Y}_{t-j} + \sum_{j=0}^{q-1} \gamma'_j \, \Delta \bar{X}_{t-j} + \lambda_i \left(Y_{i\,t-1} - \sum_{k=0}^{m} \theta_k \, X_{i\,t-k} - \rho \bar{Y}_{t-1} - \rho \bar{X}_{t-1} \right) + \varepsilon_{it} \quad (3)$$

where λ_i captures the speed at which deviations from the long-run equilibrium are corrected. A negative and statistically significant error correction coefficient provides evidence of a stable long-run relationship among the variables. Using the operational variables listed in Table 1, this model can be formulated as equation (4). In this specification, the different terms capture short-run dynamics, while the error correction component reflects the long-run equilibrium relationship among the variables. The coefficient λ_i represents the speed at which short-run deviations from equilibrium are corrected toward the long-run path. All statistical analyses in this study are conducted using RStudio.

$$\Delta EG_{it} = \alpha_i + \sum_{j=1}^{p-1} \phi_j' \, \Delta EG_{i,t-j} + \sum_{j=0}^{q-1} \beta_{1j}' \, \Delta ED_{i,t-j} + \sum_{j=0}^{q-1} \beta_{2j}' \, \Delta ER_{i,t-j} + \sum_{j=0}^{q-1} \beta_{3j}' \, \Delta FDI_{i,t-j} + \sum_{j=0}^{q-1} \beta_{4j}' \, \Delta INF_{i,t-j} + \sum_{j=0}^{q-1} \beta_{5j}' \, \Delta BOT_{i,t-j} + \sum_{j=0}^{p-1} \delta_j' \, \Delta \overline{EG}_{t-j} + \sum_{j=0}^{q-1} \gamma_{1j}' \, \Delta \overline{ED}_{t-j} + \sum_{j=0}^{q-1} \gamma_{2j}' \, \Delta \overline{ER}_{t-j} + \sum_{j=0}^{q-1} \gamma_{3j}' \, \Delta \overline{FDI}_{t-j} + \sum_{j=0}^{q-1} \gamma_{4j}' \, \Delta \overline{INF}_{t-j} + \sum_{j=0}^{q-1} \gamma_{5j}' \, \Delta \overline{BOT}_{t-j} + \lambda_i \big(EG_{i,t-1} - \theta_0 - \theta_1 ED_{i,t-1} - \theta_2 ER_{i,t-1} - \theta_3 FDI_{i,t-1} - \theta_4 INF_{i,t-1} - \theta_5 BOT_{i,t-1} - \rho_0 \overline{EG}_{t-1} - \rho_1 \overline{ED}_{t-1} - \rho_2 \overline{ER}_{t-1} - \rho_3 \overline{FDI}_{t-1} - \rho_4 \overline{INF}_{t-1} - \rho_5 \overline{BOT}_{t-1} \big) + \varepsilon_{it} \quad (4)$$

RESULTS AND DISCUSSION

Table 2 presents the descriptive statistics of the variables used in this study. Economic growth (EG) has a mean of 4.60, a median of 5.02, and a standard deviation of 3.02, with values ranging from –13.13 to 15.33. External debt (ED) records an average of 128.29 and a median of 71.50, with a high standard deviation of 130.89. The exchange rate (ER) has a mean of 1.83 and a median of 0.14, and a standard deviation of 6.39. Foreign direct investment (FDI) has a mean of –4.60 and a median of –2.17, with values ranging from –46.07 to 4.55. Inflation (INF) records an average of 13.56 and a median of 8.18. Besides, the balance of trade (BOT) has a mean of –7.52 and a median of –6.02, with values ranging from –68.87 to 42.72, demonstrating considerable variation in trade performance.

Table 3 presents the Variance Inflation Factor (VIF) results for the independent variables. The VIF values range from 1.0113 to 1.5687, with all values well below the commonly accepted threshold of 10. This indicates the absence of multicollinearity among

external debt (ED), exchange rate (ER), foreign direct investment (FDI), inflation (INF), and balance of trade (BOT). Therefore, the estimated regression coefficients are considered reliable and free from multicollinearity concerns.

Table 2. Descriptive Statistics

Variables	Mean	Median	Std. Dev.	Min.	Max.
EG	4.60	5.02	3.02	−13.13	15.33
ED	128.29	71.50	130.89	14.26	514.99
ER	1.83	0.14	6.39	0.00	65.85
FDI	−4.60	−2.17	5.99	−46.07	4.55
INF	13.56	8.18	18.00	−0.40	143.64
BOT	−7.52	−6.02	17.66	−68.87	42.72

Table 4 presents the results of the cross-sectional dependence (CSD) tests. The Pesaran CD test yields a statistic of 2.8958 with a p-value of 0.003782, which is significant at the 1% level. Likewise, the Breusch–Pagan LM test and the Scaled LM test yield p-values of 0.02377 and 0.02077, respectively, both significant at the 5% level. Since all p-values are below 0.05, the results indicate cross-sectional dependence among the countries in the panel. This result is consistent with existing literature, which documents cross-sectional dependence across various economic integrations and trading blocs. For example, studies focusing on the African region (Gómez & Irewole, 2024) and the Asian region (Dawood et al., 2021) report similar findings. Previous research has also identified cross-sectional dependence among Developing-8 member countries (Sajid et al., 2025). Consequently, second-generation panel data techniques that account for cross-sectional dependence are more appropriate for the subsequent empirical analysis.

Table 3. Variance Inflation Factor

Variables	Variance Inflation Factor
ED	1.556127
ER	1.499075
FDI	1.536375
INF	1.568728
BOT	1.011344

Table 4. Cross-Sectional Dependence (CSD) Tests Results

Tests	Statistic	p-value
Pesaran CD	2.8958 (z)	0.00378 ***
Breusch–Pagan LM	27.664 (χ^2)	0.02377 **
Scaled LM	2.3122 (z)	0.02077 **

Note: *** significant at 1%, ** significant at 5%

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The Cross-Sectionally Augmented IPS (CIPS) unit root test on Table 5 was employed to examine the stationarity properties of the variables while accounting for cross-sectional dependence. The results indicate that EG, ER, INF, and BOT are stationary at their levels, as their CIPS statistics are below the critical value at the 5% significance level (approximately –2.33). In contrast, ED and FDI are non-stationary in levels but become stationary after first differencing, indicating that they are integrated of order 1 (I(1). Overall, the findings reveal a mixture of I(0) and I(1) variables, with no variable integrated of order two, I(2). This satisfies the necessary condition for applying the panel ARDL model.

Table 5. Cross-Sectionally Augmented IPS (CIPS) Root Test Results

Variables	CIPS Value at Level/I(0)	CIPS Value at First Difference/I(1)	Order
EG	−3.5094	−7.4384	I(0)
ED	−1.1424	−2.7633	I(1)
ER	−5.9834	−9.7521	I(0)
FDI	−1.3873	−5.6502	I(1)
INF	−3.4742	−7.3544	I(0)
BOT	−2.9861	−4.7039	I(0)

Table 6 presents the results of the optimal lag length selection. Based on the information criteria, the optimal lag length is the one selected by the model with the lowest criterion value. The Akaike Information Criterion (AIC) reaches its minimum value of 25.12685 at lag 2, while the Hannan–Quinn Criterion (HQ) and Schwarz Criterion (SC) attain their lowest values of 25.75132 and 26.22099, respectively, at lag 1. Since AIC is generally preferred in panel ARDL studies for capturing more dynamic relationships by selecting a less restrictive lag structure, lag 2 is chosen as the optimal lag length for the subsequent analysis. This lag specification is expected to adequately capture both the short-run and long-run dynamics among the variables included in the model.

Table 6. Optimal Lag Length Selection

Lag	AIC	HQ	SC
1	25.43039	25.75132	26.22099
2	25.12685	25.72287	26.59511
3	25.25996	26.13107	27.40589

Table 7 presents the Cross-Sectionally Augmented ARDL estimation results for the immediate effects of the explanatory variables on economic growth. The results indicate that external debt (ED) has a positive effect on economic growth. Similarly, the exchange

rate (ER) exerts a positive impact on economic growth. In contrast, inflation (INF) and balance of trade (BOT) have negative effects on economic growth. This result implies that increases in inflation and deterioration in the trade balance are associated with lower economic growth. Foreign direct investment (FDI), however, has a negative coefficient of –0.019036 but is not statistically significant (p = 0.6968), indicating no immediate effect on economic growth. The coefficient of the cross-sectional average of economic growth is positive, suggesting the presence of common factors affecting economic growth across countries. Meanwhile, the cross-sectional averages of the explanatory variables are statistically insignificant, indicating that their common cross-sectional components do not exert a significant immediate influence on economic growth.

Table 7. Cross-Sectional Augmented ARDL Estimation Results (Immediate Effect)

Variables	Coefficient	Std. Error	t-Statistic	p-value
ED	0.021424	0.009433	2.2713	0.0248 **
ER	0.139726	0.047105	2.9663	0.0036 **
FDI	−0.019036	0.048737	−0.3906	0.6968
INF	−0.047372	0.017816	−2.6590	0.0089 **
BOT	−0.062618	0.018135	−3.4529	0.0008 ***
EG	1.004310	0.309432	3.2457	0.0015 **
ED	−0.021457	0.049239	−0.4358	0.6638
ER	−0.158691	0.933806	−0.1699	0.8653
FDI	0.021278	0.181427	0.1173	0.9068
INF	0.046340	0.104018	0.4455	0.6567
BOT	0.061994	0.104808	0.5915	0.5553

Note: *** significant at 1%, ** significant at 5%

Table 8 presents the Cross-Sectionally Augmented ARDL estimation results incorporating the delayed effects of external debt, exchange rate, foreign direct investment (FDI), inflation, and balance of trade on economic growth. For the first lag, economic growth (EG_lag1) has a positive effect on current economic growth, indicating persistence over time. External debt (ED_lag1) has a significant negative effect at the 10% level, implying that higher external debt in the previous period may slightly reduce economic growth in the current period. Balance of trade (BOT_lag1) has a positive impact on economic growth, indicating that improvements in the balance of trade contribute to higher economic growth. Meanwhile, exchange rate (ER_lag1), foreign direct investment (FDI_lag1), and inflation (INF_lag1) do not show statistically significant effects at the first lag.

At the second lag, several explanatory variables become significant. Economic growth (EG_lag2) remains positively associated with current growth, further confirming

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the persistence of growth dynamics. Exchange rate (ER_lag2) has a negative effect on economic growth, suggesting that exchange rate fluctuations may adversely affect economic performance after two periods. In contrast, foreign direct investment (FDI_lag2) positively influences economic growth, suggesting that FDI benefits are realized over time rather than immediately. Similarly, inflation (INF_lag2) has a positive effect, while balance of trade (BOT_lag2) continues to exhibit a positive effect. However, external debt (ED_lag2) does not significantly affect economic growth. The coefficients of the cross-sectional averages of economic growth, external debt, exchange rate, foreign direct investment, inflation, and balance of trade are statistically insignificant at both lags. This suggests that the common factors captured by these cross-sectional averages do not directly affect economic growth in the sample.

Table 8. Cross-Sectional Augmented ARDL Estimation Results (Delayed Effect)

Variables	Coefficient	Std. Error	t-Statistic	p-value
EG_lag1	0.172903	0.078220	2.2105	0.0289 **
ED_lag1	−0.017558	0.010095	−1.7393	0.0844 *
ER_lag1	0.026807	0.052882	0.5069	0.6131
FDI_lag1	−0.060358	0.053771	−1.1225	0.2638
INF_lag1	0.007209	0.018625	0.3871	0.6994
BOT_lag1	0.053100	0.020983	2.5307	0.0126 **
EG_lag1	−0.171647	0.312566	−0.5492	0.5839
ED_lag1	0.016964	0.056083	0.3025	0.7628
ER_lag1	0.020454	0.928925	0.0220	0.9825
FDI_lag1	0.059070	0.297219	0.1987	0.8428
INF_lag1	−0.006853	0.070633	−0.0970	0.9229
BOT_lag1	−0.051888	0.111919	−0.4636	0.6437
EG_lag2	0.141455	0.076073	1.8595	0.0653 *
ED_lag2	0.008070	0.007497	1.0764	0.2838
ER_lag2	−0.189314	0.052369	−3.6150	0.0004 ***
FDI_lag2	0.206656	0.052680	3.9229	0.0001 ***
INF_lag2	0.042492	0.016445	2.5839	0.0109 **
BOT_lag2	0.032254	0.019033	1.6946	0.0926 *
EG_lag2	−0.140856	0.229535	−0.6137	0.5406
ED_lag2	−0.007169	0.055171	−0.1299	0.8968
ER_lag2	0.170218	0.688388	0.2473	0.8051
FDI_lag2	−0.207525	0.247111	−0.8398	0.4026
INF_lag2	−0.041772	0.058025	−0.7199	0.4729
BOT_lag2	−0.032483	0.106187	−0.3059	0.7602

Note: *** significant at 1%, ** significant at 5%, * significant at 1%

Table 9. ECM Estimation Results

Variable	Coefficient	Std. Error	t-Statistic	p-value
ΔED	0.048720	0.022970	2.1211	0.0359 **
ΔER	2.958486	0.564698	5.2391	0.0000 ***
ΔFDI	−0.077997	0.051417	−1.5170	0.1318
ΔINF	0.020930	0.019022	1.1003	0.2733
ΔBOT	−0.002836	0.021243	−0.1335	0.8940
ΔEG_lag1	−0.172697	0.088039	−1.9616	0.0520 *
ΔED_lag1	−0.017677	0.021926	−0.8062	0.4216
ΔER_lag1	−1.957646	0.570824	−3.4295	0.0008 ***
ΔFDI_lag1	0.238584	0.077022	3.0976	0.0024 ***
ΔINF_lag1	−0.035576	0.019292	−1.8441	0.0675 *
ΔBOT_lag1	−0.005024	0.021282	−0.2361	0.8138
ΔEG_lag2	−0.051869	0.072440	−0.7160	0.4753
ΔED_lag2	−0.031903	0.020876	−1.5282	0.1290
ΔER_lag2	0.108324	0.324482	0.3338	0.7391
ΔFDI_lag2	0.095216	0.083190	1.1446	0.2546
ΔINF_lag2	−0.001628	0.015695	−0.1037	0.9175
ΔBOT_lag2	0.070975	0.021615	3.2837	0.0013 ***
$ECT_{(t-1)}$	−0.346587	0.108393	−3.1975	0.0018 ***

Note: *** significant at 1%, ** significant at 5%, * significant at 1%

Table 9 presents the Error Correction Model (ECM) estimation results, which capture the short-run dynamics among external debt, exchange rate, foreign direct investment (FDI), inflation, trade balance, and economic growth. The results indicate that changes in external debt (ΔED) and exchange rate (ΔER) have positive effects on economic growth in the short run, with coefficients of 0.0487. In contrast, changes in FDI (ΔFDI), inflation (ΔINF), and balance of trade (ΔBOT) do not exert significant contemporaneous effects on economic growth.

Regarding lagged effects, the first lag of economic growth (ΔEG_lag1) is negative, indicating a partial adjustment process. The first lag of the exchange rate (ΔER_lag1) has a negative effect, suggesting that the initial positive impact of exchange rate changes reverses in the subsequent period. Meanwhile, the first lag of FDI (ΔFDI_lag1) positively affects economic growth, suggesting that the benefits of foreign investment are delayed. The first lag of inflation (ΔINF_lag1) has a weak negative effect that is significant at the 10% level, whereas the first lag of external debt remains insignificant. Among the second-lag variables, only the balance of trade (ΔBOT_lag2) has a positive effect on economic growth, implying that improvements in trade performance contribute to growth after a two-period delay. The remaining second-lag variables are statistically insignificant, indicating limited delayed effects beyond the first lag.

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Most importantly, the Error Correction Term, ECT(t–1), is negative and highly significant, confirming the existence of a stable long-run equilibrium relationship among the variables. The negative sign is consistent with the ECM theory and indicates that deviations from the long-run equilibrium are corrected over time. Specifically, approximately 34.66% of any disequilibrium is adjusted within one period, implying a moderate speed of convergence toward long-run equilibrium following short-run shocks.

The Cross-Sectionally Augmented ARDL results indicate that external debt has a positive and statistically significant immediate effect on economic growth, suggesting that external borrowing supports economic expansion by providing additional financial resources for infrastructure, public investment, and other productive activities. In developing economies with limited domestic savings, external debt can help bridge financing gaps and stimulate aggregate demand. This finding is consistent with previous studies showing that external financial resources promote economic growth by supplementing domestic capital and supporting productive investment (Abduvaliev & Bustillo, 2024; Afolabi Ibikunle et al., 2023; Ayenew, 2022; Choi & Kim, 2024; Luu et al., 2024; Musse et al., 2024). However, the finding differs from studies that documented a negative relationship between external debt and economic growth, particularly when debt accumulation becomes excessive (Ayana et al., 2023; Dawood et al., 2021; Gaies & Nabi, 2021; Luu et al., 2024; Mohamed & Bile Mohamud, 2025). A possible explanation for this difference is that most of these studies focused on the long-run consequences of debt accumulation. In contrast, the present study captures the immediate effect of external borrowing. While external debt may generate short-run growth benefits through increased investment and expenditure, excessive debt accumulation may eventually reduce growth by imposing higher debt-servicing obligations and imposing fiscal constraints, as predicted by the Debt Overhang Theory.

The results further show that the exchange rate has a positive and statistically significant immediate effect on economic growth, suggesting that exchange rate depreciation enhances export competitiveness by lowering the relative price of domestic goods, thereby increasing export demand, production, and economic activity. This finding is consistent with previous studies highlighting the importance of exchange rate movements in influencing economic performance through trade and investment channels (Gold & Tregenna, 2024; Nazamuddin et al., 2024; Oyadeyi et al., 2025; Rashed et al., 2022; Zahra et al., 2023; Zhu et al., 2025). However, the negative lagged effect identified in this study is more consistent with findings suggesting that prolonged exchange rate volatility creates uncertainty, increases import costs, raises production expenses, and discourages investment (Bhat et al., 2024; Buthelezi, 2023; Giordano, 2023; Ramos-Herrera, 2024; Sheykhi et al., 2025). The coexistence of positive short-run and negative delayed effects suggests that exchange rate depreciation may initially stimulate growth through export competitiveness. However, persistent instability can eventually undermine economic performance through inflationary pressures and increased uncertainty.

The findings indicate that foreign direct investment (FDI) does not have a statistically significant immediate effect on economic growth, although its impact becomes positive and highly significant over time. This suggests that the benefits of FDI are realized gradually as foreign firms establish operations, transfer technology, develop human capital, and

generate productivity spillovers. The positive lagged effect is consistent with evidence that the growth-enhancing benefits of FDI emerge primarily in the long run (Asafo-Adjei et al., 2023; Mejia, 2023; Triatmanto et al., 2023; Ullah et al., 2022). However, the insignificant immediate effect differs from studies that report a direct positive relationship between FDI and economic growth. This difference may be explained by variations in absorptive capacity, institutional quality, infrastructure development, and the time required for foreign investment projects to become operational. Therefore, the findings suggest that FDI contributes more effectively to long-run economic growth than to short-run economic expansion.

Inflation has a negative and statistically significant immediate effect on economic growth. This result indicates that rising prices reduce purchasing power, increase production costs, create uncertainty, and discourage private investment. This finding is consistent with studies showing that inflation adversely affects economic growth by weakening investment incentives and macroeconomic stability (Helmy, 2022; Ibrahim et al., 2022; Ozili, 2025; Rashed et al., 2022). However, the positive lagged effect observed in this study differs from research reporting a consistently negative relationship between inflation and growth. Instead, it supports the argument that moderate inflation may reflect stronger aggregate demand and expanding economic activity (Ibrahim et al., 2022). This finding implies that the relationship between inflation and economic growth may be nonlinear: low or moderate inflation can accompany economic expansion, whereas excessive inflation is detrimental to economic performance.

The balance of trade is found to have a negative immediate effect on economic growth but a positive lagged effect. The negative short-run impact may reflect structural trade imbalances, dependence on imported intermediate goods, and external shocks on domestic production. However, the positive lagged effect suggests that improvements in trade performance eventually promote economic growth by boosting export earnings, increasing foreign exchange accumulation, facilitating technology transfer, and driving productivity gains. This finding is consistent with evidence that trade expansion enhances economic growth by increasing market access and efficiency (Abendin & Duan, 2021; Abille & Meçik, 2023; Kinfack & Bonga-Bonga, 2023; Sajid et al., 2025; Sharmiladevi, 2023). However, the negative contemporaneous effect differs from that reported in studies that report exclusively positive trade-growth relationships. This discrepancy may arise because many previous studies focus on long-run trade performance, whereas the present study distinguishes between immediate and delayed effects. The findings therefore suggest that the growth benefits of trade require time to materialize through investment, production adjustments, and export expansion.

CONCLUSION

Economic growth in selected Developing-8 countries during 1997–2024 is influenced by external debt, exchange rates, foreign direct investment (FDI), inflation, and the trade balance through both short-run and long-run channels. The results show that external debt and the exchange rate positively affect economic growth in the short term, while inflation and the trade balance negatively affect economic growth. In contrast,

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FDI does not significantly affect growth in the short run but contributes positively over the long run. The delayed-effect analysis further indicates that external debt and the exchange rate may hinder growth in subsequent periods, whereas FDI, inflation, and the trade balance exert positive lagged effects. Furthermore, the ECM results confirm a stable long-run equilibrium relationship among the variables, with approximately 34.66% of short-run disequilibrium adjusted toward equilibrium within one period.

Based on these findings, policymakers in Developing-8 countries should implement prudent fiscal policies by limiting excessive external borrowing and allocating debt-financed expenditures to productive sectors, such as infrastructure, education, and technology development. Monetary authorities should maintain a stable and predictable exchange rate while adopting a moderately contractionary monetary policy when inflationary pressures intensify to preserve price stability and macroeconomic stability. In addition, governments should pursue expansionary structural policies that attract technology-intensive, export-oriented foreign direct investment, promote export diversification, and strengthen trade competitiveness by improving trade infrastructure and the business environment.

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How Do Digital Readiness and Economic Growth Compare Across Income Groups?

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ABSTRACT

Research Originality: This study provides new empirical evidence on the global impact of digital readiness on economic growth by comparing high-, middle-, and low-income countries. Unlike previous studies focusing on single countries or regions, this research examines whether digital readiness contributes differently across income groups.

Research Objectives: This study aims to explore the development of digital readiness and analyze its effect on economic growth across countries by income level.

Research Methods: The study uses descriptive analysis and panel-data regression across 105 countries for 2019–2023. Digital readiness is measured by the Networked Readiness Index, comprising 46 indicators. PCA is applied to construct the index, and panel regression examines the relationship between digital readiness and economic growth across income groups.

Empirical Results: Digital readiness significantly boosts economic growth across all income groups, with the strongest effect in high-income countries, a moderate effect in middle-income countries, and the weakest in low-income countries.

Implications: The findings show that digital readiness has become a key driver of global economic growth, reflecting increasing access to and adoption of digital technologies across countries at different income levels.

Keywords:

cross-country analysis; digital infrastructure adoption; economic development; income group comparison; technological preparedness

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INTRODUCTION

The relationship between digital technology and economic growth has become one of the most contested and consequential debates in contemporary development economics (Ping et al., 2026). As globalization intensifies, Information and Communication Technology (ICT) has emerged as a structural driver of productivity, trade, and innovation. Yet, the mechanisms through which it translates into growth remain deeply contested, particularly across countries at different stages of development. Understanding why digital readiness produces divergent economic outcomes across income groups lies at the heart of this study (Sarsar & Echaoui, 2026). The world in the era of globalization faces major challenges that affect economic growth (Ahmed et al., 2026). Today, virtually everything can be controlled remotely across various regions via the internet using technological devices. This is inseparable from the influence of rapidly advancing Information and Communication Technology (ICT), which fosters the digital economy within a country (Cheng et al., 2026; Mukherjee, 2026).

The use of digital technology has been increasing, particularly since the onset of the COVID-19 pandemic in early 2020, which led to restrictions on various community activities. This situation has driven people to increase their use of digital technology to meet their needs, including working and learning from home, *online shopping,* and other activities that require it. This has led to an increase in demand for internet and mobile data services (WTO, 2020). We Are Social (2023) notes in its annual *Digital Report* that, as of January 2023, *digital traffic* trends have continued to rise post-COVID-19. Among these trends, 59.8% of global internet users are shopping online more frequently in the post-pandemic era, with the largest increase in online shopping occurring in the *fashion & food* categories, at 37%. The number of consumer transactions via online e-commerce also increased by 8.3%, totaling 4.11 billion.

The *Global Information Technology Report* (GITR), published by *the World Economic Forum* (WEF), examines various indicators of a country's readiness for digitalization. These individual indicators are aggregated to produce pillar scores, which are then combined to generate sub-index scores and ultimately merged to produce the *Networked Readiness Index* (NRI), also known as the Digital Readiness Index, as it is used to assess a country's ability to leverage the digital revolution. *The Networked Readiness Index* (NRI) underwent a model update in 2019. *The* 2023 *Networked Readiness Index* is the fifth edition of the updated NRI model published by the Portulans Institute in collaboration with the University of Oxford. The 2023 NRI comprises 58 indicators distributed across 12 sub-pillars and consolidated into 4 main pillars (aspects): the technology aspect, the human resources aspect, the governance aspect, and the SDG contribution aspect (NRI Model, 2023). This index aims to conceptualize the complex reality of information and communication technology (ICT) and identify common factors that enable countries to use technology effectively. The indicator framework in the NRI is intended to guide policymakers and civil society on the factors they need to consider and account for to leverage ICT in their growth strategies.

The top 10 countries with the highest NRI scores in 2023 are all *high-income economies,* comprising a mix of Asian countries (Singapore and South Korea) and European

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countries (Finland, the Netherlands, Sweden, Switzerland, Denmark, and Germany), as well as the United States. Europe remains the region with the most advanced technology, accounting for 7 of the top 10 countries in the NRI index. Among developing countries in Asia *(lower- and upper-middle-income),* the top five in overall digital readiness are China, Malaysia, Thailand, Vietnam, and Indonesia. In the Americas region, the top three developing countries are Brazil, Costa Rica, and Argentina. In the MENAP region *(Middle East, North Africa, and Pakistan)*, the United Arab Emirates (ranked 30th) and Saudi Arabia (ranked 41st) continue to lead the Arab world in network readiness. Meanwhile, among Sub-Saharan African countries—most of which are *low-* and *middle-income*—the highest NRI index is held by Kenya (ranked 70th), followed by South Africa (ranked 74th).

The differences in the impact of ICT on economic growth between developed and developing countries are illustrated in a study by the International Telecommunication Union (2018), which found that *fixed broadband* has had a significant impact on the global economy over the past seven years (2010–2017). A 1 percentage point increase in *fixed broadband* penetration results in a 0.08 percentage point increase in economic growth (GDP). Second, based on the *mobile broadband* model*,* a 1 percentage point increase in *mobile broadband* penetration results in a 0.15 percentage point increase in GDP. Third, the economic impact generated by *fixed broadband* penetration (through *the returns-to-scale* effect) is higher in more developed countries than in less developed ones. On the other hand, the economic impact of *mobile broadband* penetration is more significant in less developed countries than in more developed ones. Also demonstrates that ICT plays a major role in the growth of high-income and upper-middle-income countries, but fails to contribute to the growth of lower-middle-income countries.

Prior studies have examined the relationship between ICT and economic growth using various approaches. Niebel (2014) found a positive relationship between ICT capital and GDP growth but did not identify statistically significant differences in the output elasticity of ICT across developing, emerging, and developed countries, thereby questioning the 'leapfrogging' hypothesis. Bahrini and Qaffas (2019) showed that mobile phone use, internet use, and broadband adoption positively and significantly affect economic growth, while fixed telephone use had a negative impact in developing country contexts. Myovella & Haucap (2020) found that digitalization contributes positively to economic growth in both groups of countries, with mobile telecommunications and broadband internet exhibiting different magnitudes of effect between OECD and SSA countries. Further studies using multi-country panel frameworks confirmed long-run relationships among ICT infrastructure, capital formation, labor force, and per capita GDP, highlighting that ICT investment supports sustained economic growth (Pradhan et al., 2018; Pradhan et al., 2021; Awad & Albaity, 2022). These studies highlight the significant but varied impact of ICT across regions and income groups, setting the stage for research on more comprehensive measures.

Building on this literature, recent studies have employed the Networked Readiness Index (NRI) to capture digital readiness more holistically. Silva et al. (2022) show that the NRI captures key dimensions of digital technologies and their implications for economic

and social progress. However, debates remain on its capacity to address digital divides. Prasetyo & Mulyana (2025) examine the impact of the NRI's four pillars on GDP growth in 21 East Asia and Pacific countries (2019–2024), finding that Technology and Governance significantly influence economic growth, while People and Impact do not show statistically significant effects, highlighting the importance of digital infrastructure and effective governance. Hammache (2024) demonstrates a positive association between digitalization, measured by NRI sub-indexes, and economic growth in the Middle East and North Africa, although some human capital indicators show limited significance. Methodological studies also explore the structure and measurement of NRI. Tokmergenova & Dobos (2023) apply Principal Component Analysis to map relationships among NRI sub-pillars, providing insights into the dimensionality and clustering of digital-readiness patterns, while Bánhidi & Dobos (2024) propose alternative weighting approaches to rank digital development using NRI, emphasizing measurement challenges and comparative frameworks. Despite these advances, the literature rarely offers global comparisons of how overall digital readiness impacts economic growth across different income groups.

This study addresses these gaps through three contributions. First, it employs the NRI as a holistic, multidimensional measure of digital readiness, going beyond single-indicator proxies used in prior research. Second, it applies Principal Component Analysis (PCA) to identify the dominant NRI determinants driving digital readiness across country groups. Third, it simultaneously compares the impact of digital readiness on economic growth across high-, middle-, and low-income countries using panel data for 105 countries over 2019–2023. This period uniquely encompasses the COVID-19 digital transformation surge and its aftermath. Accordingly, this study pursues two objectives: (1) to explore the development of digital readiness as measured by the NRI across income groups, and (2) to analyze the differential impact of digital readiness on economic growth across high-, middle-, and low-income countries at the global level.

METHODS

This study uses secondary data obtained from existing sources (Hasan, 2002), specifically global data sources such as the World Bank and the Networked Readiness Index Report, spanning 5 years (2019–2023). The quantitative analysis methods employed include principal component analysis (PCA) and panel data regression (pooled data), processed using Stata software, supported by descriptive analysis drawing on scientific journals, books, and previous studies. The data used for this study are presented in Table 1.

Before the in-depth analysis, data cleansing removed duplicate, inconsistent, and incomplete records (including those with missing values), reducing the initial sample from 133 to 105 countries (28 removed) and the NRI indicators from 58 to 46 (12 removed). The final dataset comprises panel data from 105 countries (48 high-income, 52 middle-income, and 5 low-income) over 2019–2023, with 46 NRI indicators and 525 observations in total. These 5 years were used because complete and consistent NRI data were only available up to 2023, ensuring reliability and comparability across countries.

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Table 1. Variables and Data Sources

Variables	Description	Unit	Source
LnGDP	Gross domestic product	Million USD	World Bank
LnGCF	Gross capital formation	Million USD	World Bank
LnLF	Labor force population	People	World Bank
INFLCPI	Inflation	Annual %	World Bank
LnGE	Government spending	Million USD	World Bank
EDC	Minimum education attainment rate: bachelor's degree or equivalent	Annual %	World Bank
NRI	Digital readiness index	Score 0-100	NRI Report

This study employs three analytical methods to examine the impact of digital readiness on economic growth: principal component analysis (PCA), score plot analysis, and panel data regression using the Random-Effects approach. Principal Component Analysis (PCA) is used to reduce the 46 NRI indicators into a smaller number of new variables that represent the original set and capture the dominant factors shaping the NRI; the number of components formed equals the number of original variables (Supartoyo, 2018).

Scoreplot analysis, part of PCA, maps the 105 countries into quadrants I–IV based on each country's PC1 and PC2 values: Quadrant I (high PC1, high PC2), Quadrant II (high PC1, low PC2), Quadrant III (low PC1, low PC2), and Quadrant IV (low PC1, high PC2). Panel data regression combines cross-sectional and time-series data, allowing for control of unobserved heterogeneity and a more comprehensive analysis of dynamic effects among variables (Ghanim, 2026). Three general estimation models are commonly applied: the Common Effect Model (Pooled Least Squares), the Fixed Effect Model, and the Random Effect Model (Kwon, 2026). This study applies Generalized Least Squares (GLS) using the Random Effects approach, selected directly based on the purpose of the analysis, with model adequacy assessed using R^2, the F-test, and the t-test. The model used in this study is:

$$\begin{aligned} LnGDP_{it} = {} & \alpha_{0i} + \alpha_1 \, lnGCF_{it} + \alpha_2 \, lnLF_{it} + \alpha_3 \, lnflcpi_{it} + \alpha_4 \, lnGE_{it} + \alpha_5 \, EDC_{it} + \\ & \alpha_6 \, NRI_{it} + \alpha_7 DhNRI_{it} + \alpha_8 DmNRI_{it} + u_{1it} \end{aligned} \quad (1)$$

Where:

GDP = Gross Domestic Product/Economic Growth (million USD); GCF = Gross Capital Formation/Total Investment (million USD); LF = Total Labor Force/Working-Age Population (people); Inflcpi = Inflation (annual percentage); GE= Government Expenditure (million USD); EDC= Minimum educational attainment rate at bachelor's degree or equivalent (percent); NRI = Networked Readiness Index/Digital Readiness Index (index 1–100); DhNRI = Interaction dummy variable between NRI and high-income countries (1 = high-income country, 0 = other countries); DmNRI = interaction dummy

variable between NRI and middle-income countries (1 = middle-income country, 0 = other countries); u = error term; i = country; i = 1, 2, 3, …, 105; and t = year; t = 1, 2, 3, 4, 5

RESULTS AND DISCUSSION

Principal Component Analysis (PCA) of the 46 indicator variables comprising the NRI yielded three new variables (principal components) that accounted for 60.90% of the total variance, indicating that the Digital Readiness Index (NRI) can be explained by just these three derived variables. The three new variables formed by the PCA analysis are PC1 (Digital Well-being and Social Connectivity), PC2 (Innovation Ecosystem and Digital Transformation), and PC3 (Technology Infrastructure and Digital Economy). These three variables are the factors that most influence the NRI index. The results of the scoreplot analysis at illustrate the digital readiness of 105 countries. PCA analysis confirms that high-income countries rank higher on the Digital Readiness Index in nearly all aspects (all indicators). The country with the lowest PC1 score is Ethiopia (in the low-income country category), indicating very low scores for Digital Well-being and Social Connectivity.

Meanwhile, the country with the lowest PC2 score is Greece (in the high-income country category), indicating very low scores in the Digital Innovation and Transformation Ecosystem. Indonesia itself is in Quadrant IV, meaning it has a fairly good PC2 score (Digital Innovation and Transformation Ecosystem) (> 0), but a poor PC1 score (Digital Well-being and Social Connectivity) (< 0). The results of the regression analysis examining the relationship between the Digital Readiness Index and economic growth (GDP) indicate that the Digital Readiness Index (NRI) significantly boosts economic growth across all income groups of countries, with the greatest impact in high-income countries (61.9%), followed by middle-income countries (30.4%), and low-income countries (0.2%). This study indicates that digital readiness has now become a relevant driver of economic growth across all income groups of countries, in line with the increasing access to and penetration of digital technology in recent years.

The final data (scores 0–100) were used to calculate the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy, which assesses sample adequacy by comparing observed and partial correlations and must exceed 0.50 for PCA to proceed. The KMO result of 0.6038 indicates sufficient, though moderate, inter-variable correlation, confirming that the 46 NRI indicators capture a reasonably diverse yet interconnected set of digital readiness dimensions and justifying the use of PCA to condense them into fewer interpretable components without significant information loss. With the KMO check confirming the dataset's suitability, the PCA analysis proceeds by calculating correlations among variables (Li & Li, 2026), organizing them into a correlation matrix, and examining the eigenvalues (characteristic roots) of each variable. In this study, the new principal components are based on eigenvalues greater than 6, as shown in Table 2.

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Table 2. Eigenvalues and Variance Contributions by Indicator

Component	Eigenvalue	Cumulative	Variance (%)	Component	Eigenvalue	Cumulative	Variance (%)
Comp 1	19.2465	0.4184	41.84	Comp 24	0.1900	0.9713	0.41
Comp 2	6.0506	0.5499	13.15	Comp 25	0.1789	0.9752	0.39
Comp 3	2.7170	0.6090	5.91	Comp 26	0.1633	0.9788	0.36
Comp 4	2.1235	0.6552	4.62	Comp 27	0.1326	0.9817	0.29
Comp 5	2.0921	0.7006	4.55	Comp 28	0.1105	0.9841	0.24
Comp 6	1.5941	0.7353	3.47	Comp 29	0.1061	0.9864	0.23
Comp 7	1.5503	0.7690	3.37	Comp 30	0.0929	0.9884	0.20
Comp 8	1.1414	0.7938	2.48	Comp 31	0.0848	0.9902	0.18
Comp 9	1.0737	0.8172	2.33	Comp 32	0.0655	0.9917	0.14
Comp 10	0.7996	0.8345	1.74	Comp 33	0.0598	0.9930	0.13
Comp 11	0.7821	0.8515	1.70	Comp 34	0.0593	0.9943	0.13
Comp 12	0.6830	0.8664	1.48	Comp 35	0.0521	0.9954	0.11
Comp 13	0.6586	0.8807	1.43	Comp 36	0.0425	0.9963	0.09
Comp 14	0.6315	0.8944	1.37	Comp 37	0.0397	0.9972	0.09
Comp 15	0.5694	0.9068	1.24	Comp 38	0.0284	0.9978	0.06
Comp 16	0.4839	0.9173	1.05	Comp 39	0.0252	0.9983	0.05
Comp 17	0.4491	0.9271	0.98	Comp 40	0.0230	0.9988	0.05
Comp 18	0.4103	0.9360	0.89	Comp 41	0.0175	0.9992	0.04
Comp 19	0.3685	0.9440	0.80	Comp 42	0.0164	0.9996	0.04
Comp 20	0.3122	0.9508	0.68	Comp 43	0.0088	0.9998	0.02
Comp 21	0.2772	0.9569	0.60	Comp 44	0.0061	0.9999	0.01
Comp 22	0.2597	0.9625	0.56	Comp 45	0.0031	1.0000	0.01
Comp 23	0.2161	0.9672	0.47	Comp 46	0.0011	1.0000	0.01

Figure 1. Screeplot of Eigenvalues Above Two

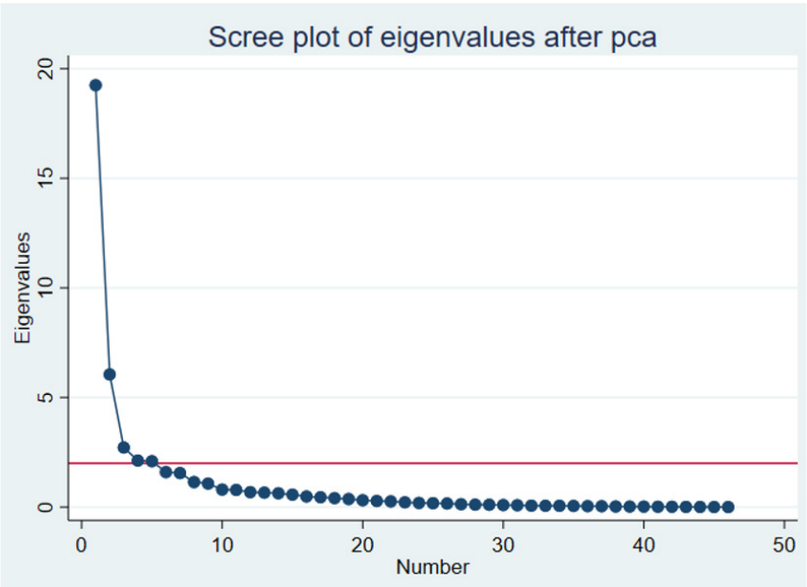

Table 2 shows the eigenvalues of each variable along with their variances. The table indicates that the PCA results yielded nine new variables (principal components) with eigenvalues greater than one. However, as shown in Figure 1, which displays the Screeplot of Eigenvalues above two, five principal components were selected as the new variables and by using one method to determine the number of new variables in PCA analysis, namely, drawing a line where the graph begins to flatten (a kink in the line), only three variables (three principal components) are selected as new variables. Eigenvalues greater than one indicate significant PC loading (Moniruzzaman, 2026).

A more detailed explanation is shown in the pie chart in Figure 2, which indicates that Component 1 accounts for 41.84% of the variance. When Components 2 and 3 are added, the total variance contribution exceeds 60%. Meanwhile, in that pie chart, it can be seen that the percentage of variance added by Component 4 and subsequent components is below 5% and continues to decrease (becoming increasingly insignificant). Therefore, this study will only use the three principal components (Components 1, 2, and 3) as new variables. These three new variables account for 60.90% of the data's variance (as seen in the total percentage of variance). To determine which variables are included in these three new variables and which truly influence the Networked Readiness Index (NRI), factor rotation (transformation) was performed using the varimax rotation method. Next, the factor loadings of each variable forming each principal component were examined. Variables with high factor loadings for a component indicate a strong relationship between that factor and the component (Bogaert et al., 2026; Anna et al., 2026).

Figure 2. Pie Chart of Contribution by Indicator

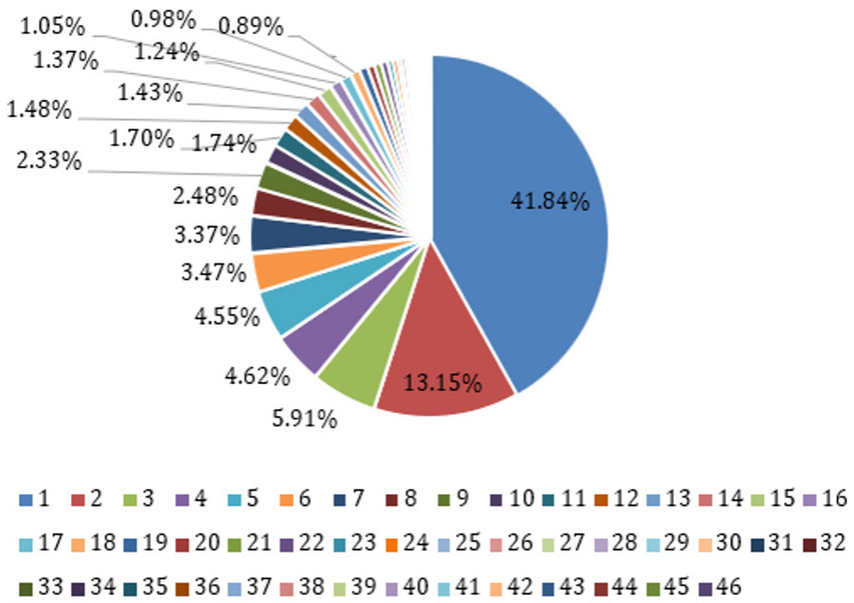

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Table 3. Factor Loadings per Indicator

Indicator	Comp1	Comp2	Comp3	Indicator	Comp1	Comp2	Comp3
A1	0.1559	0.0498	0.0621	C4	0.2335*	0.0022	0.0001
A2	0.1728	0.0814	-0.0203	C5	0.1224	0.1997	-0.1179
A3	-0.0561	0.0530	0.3301*	C6	0.1630	-0.0586	-0.0980
A4	0.0515	0.1362	-0.0336	C7	0.0502	0.2946*	-0.0169
A5	-0.0347	0.0527	0.3248*	C8	0.1362	-0.0143	0.0431
A6	0.1410	0.1379	-0.1112	C9	0.1045	0.0472	-0.1997
A7	0.1162	0.1398	-0.1348	C10	0.1659	0.0409	0.0734
A8	0.1707	0.0164	0.0573	C11	0.1740	0.0176	0.0165
A9	0.0174	-0.0058	0.3480*	C12	0.1388	0.1677	0.0470
A10	0.0819	0.2504*	0.0382	C13	0.1303	0.0096	-0.0541
A11	-0.0256	0.3661*	0.0284	D1	-0.0087	0.1450	0.0781
A12	0.1695	-0.0599	0.1131	D2	0.1155	0.1538	-0.0045
B1	-0.0085	0.0332	0.3716*	D3	0.0661	-0.0093	0.3668*
B2	0.2532*	-0.0937	0.0319	D4	-0.0386	0.3174*	0.0914
B3	0.3020*	-0.2354*	0.0485	D5	0.0214	0.1198	-0.1145
B4	0.1889	0.0786	-0.1028	D6	0.1890	0.0253	-0.0364
B5	0.1047	-0.0300	0.3401*	D7	-0.1279	0.3361*	-0.0671
B6	0.1706	0.0458	0.0838	D8	0.0762	0.1046	-0.0775
B7	-0.0602	0.3656*	0.0596	D9	0.2629*	-0.0930	0.0079
B8	0.1349	0.1096	0.0484	D10	0.2609*	-0.0855	0.0634
C1	0.2288*	0.0076	-0.0082	D11	0.1549	0.0001	-0.1687
C2	0.0617	0.1405	0.1682	D12	0.0733	-0.0237	-0.1219
C3	0.1223	0.1531	-0.0587	D13	0.2226*	-0.0217	0.0012

Note: *) Factor values > 0.2 are taken as indicators with the highest correlation

Table 3 shows the factor loadings describing the correlations between the original variables (46 indicators) and the new variables (principal components 1, 2, and 3) resulting from PCA. The selected factor loadings are those above 0.2, which are considered sufficient to explain the variables influencing the NRI. Other variables with factor loadings below 0.2 are considered to have little or no influence on the NRI, and the resulting variables represent the 46 indicator variables in the original data. Table 4 provides a more detailed explanation of the variables influencing the NRI and the variance each variable explains.

Table 4 shows that PC1 accounts for 41.84% of the variance and is formed by seven variables with factor values above 0.2: B2 (use of social virtual networks), B3 (college enrollment rate), C1 (secure internet servers), C4 (online shopping), D9 (life expectancy at birth), D10 (SDG 3: good health and well-being), and D13 (SDG 11: sustainable cities and communities). PC1 is named Digital Well-being and Social Connectivity, as these indicators reflect the social and digital well-being dimensions of a country's population, implying that overall digital readiness is most strongly shaped by how well countries integrate digital access with human development outcomes, suggesting that infrastructure

investment alone is insufficient without improvements in social well-being and inclusive connectivity.

Table 4. Summary of Principal Component Analysis Results

Principal components	Code	Variable name	Factor value	Explained variance
Pc1 (digital well-being and social connectivity)	B2	Use of virtual social networks	0.2532	41.84%
	B3	College enrollment rate	0.3020	
	C1	Secure internet servers	0.2288	
	C4	Online shopping	0.2335	
	D9	Healthy life expectancy at birth	0.2629	
	D10	SDG 3: good health and well-being	0.2609	
	D13	SDG 11: sustainable cities and communities	0.2226	
Pc 2 (innovation ecosystem and digital transformation)	A10	Adoption of new technologies	0.2504	13.15%
	A11	Investment in new technology	0.3661	
	B3	College enrollment rate	-0.2354	
	B7	Government incentives for investment in new technologies	0.3656	
	C7	Regulation of new technologies	0.2946	
	D4	The Rise of the gig economy	0.3174	
	D7	Freedom in making life choices	0.3361	
Pc 3 (digital technology and economic infrastructure)	A3	Internet subscription	0.3301	5.91%
	A5	International internet capacity	0.3248	
	A9	Ai publications	0.3480	
	B1	Domestic mobile *broadband* internet traffic	0.3716	
	B5	Annual Investment in Telecommunications Services	0.3401	
	D3	Domestic market size	0.3668	

PC2 accounts for 13.15% of the total variance. It is formed by seven variables: A10 (adoption of new technology), A11 (investment in new technology), B3 (college enrollment rate, with a negative loading), B7 (government incentives for technology investment), C7 (regulation of new technology), D4 (prevalence of the gig economy), and D7 (freedom to make life choices). PC2 is named the Innovation and Digital Transformation Ecosystem because its indicators reflect systemic readiness and support for innovation and digital transformation as a whole. B3's negative loading suggests that increased access to higher education does not necessarily correlate positively with digital readiness, consistent with Marginson's (2016) observation that the expansion of higher education is often not accompanied by improvements in curriculum quality or relevance to innovative industries; the OECD (2021) similarly stresses aligning higher education with 21st-century competencies and digital literacy. Together, these results suggest that strengthening the innovation and digital transformation ecosystem requires

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quality-oriented higher education reform, robust regulatory frameworks for emerging technologies, and government-backed incentives for technology investment, rather than simply expanding tertiary enrollment.

PC3 accounts for 5.91% of the total variance. It is formed by six variables: A3 (internet subscriptions), A5 (international internet capacity), A9 (AI publications), B1 (domestic mobile broadband internet traffic), B5 (annual investment in telecommunications services), and D3 (domestic market size). Named Technology and Digital Economy Infrastructure based on these characteristics, PC3 contributes the smallest share of variance, but its indicators are fundamental enablers of a digitally capable economy; countries with deficiencies in these hard infrastructure dimensions likely face a structural ceiling on the returns they can extract from digital readiness improvements captured by PC1 and PC2. In addition to generating the three principal components, the analysis mapped the positions of the 46 NRI indicators on PC1 and PC2 using a loading plot, illustrated in Figure 3.

Figure 3. Loading Plot Graph of 46 NRI Indicators

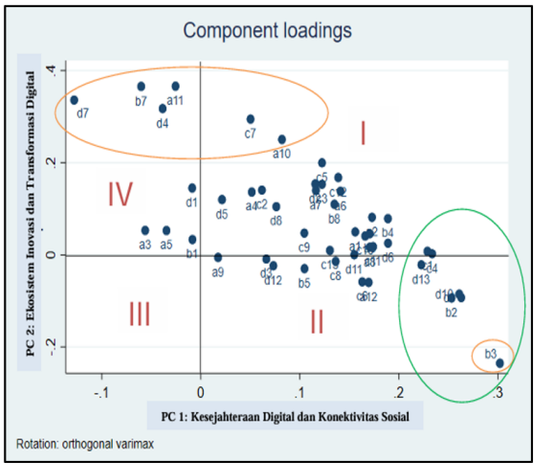
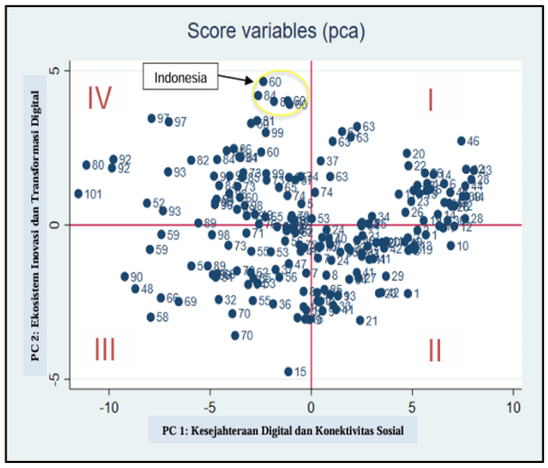


Figure 4. Scoreplot Graph of 105 Countries, 2019–2023



The seven indicators with eigenvalues > 2 on the far right of the loading plot (marked with green circles) are those forming PC1, while the six at the top and one at the bottom (orange circles) are those forming PC2, consistent with the indicators identified in Table 4. The loading plot shows that indicators in Quadrants I and II dominate PC1 (Digital Well-being and Social Connectivity), while those concentrated in Quadrant IV dominate PC2 (Innovation Ecosystem and Digital Transformation); the absence of indicators in Quadrant III indicates that all indicators contribute meaningfully to at least one component, reinforcing the validity of PCA as a dimension reduction method here.

Next, a scoreplot analysis was conducted to map the positions of 105 countries based on PC1 and PC2 values. Figure 4 illustrates the scoreplot graph in question. The group of countries in Quadrant I has high PC1 and PC2 values (> 0). Conversely, countries in Quadrant III have low PC1 and PC2 values (< 0). Countries in Quadrant II have high PC1 values (>0) but low PC2 values (<0). Finally, countries in Quadrant IV have high

PC2 values (>0) but low PC1 values (<0). The scoreplot graph shows that Quadrant I is predominantly occupied by high-income countries (country codes 1–47). Meanwhile, the countries in Quadrant III are mostly middle-income and low-income countries (country codes 48–105). These findings align with the fact that high-income countries generally have higher digital readiness indices than middle- and low-income countries. Whether in indicators reflecting digital readiness in terms of digital well-being and social connectivity (PC1), or in terms of the innovation ecosystem and digital transformation (PC2), high-income countries show positive values or are above 0. This spatial clustering indicates that the digital divide is not merely a function of internet access but a multidimensional gap encompassing social well-being, innovation capacity, and governance, dimensions that low- and middle-income countries must address simultaneously to meaningfully improve their NRI positioning.

This persistent digital divide between high- and low-income countries, as reflected in the scoreplot results, is consistent with the broader empirical literature. Niebel (2018) confirmed that ICT capital is positively associated with GDP growth across all income groups, yet found no statistically significant evidence of 'leapfrogging' advantages for developing countries, implying that high-income countries retain structural advantages in translating digital readiness into growth. In a similar vein, Myovella et al. (2020) found that while digitalization contributes positively to economic growth in both groups, the magnitude of the effects of broadband internet and mobile telecommunications differs substantially between more and less developed countries. These findings collectively reinforce the present study's scoreplot results, which show that high-income countries consistently dominate the upper quartiles of both digital well-being (PC1) and innovation ecosystem (PC2) dimensions of the NRI.

In Figure 4, Indonesia (code 60) is positioned in Quadrant IV, with a fairly high PC2 value (> 0) but a low PC1 value (< 0), indicating that its innovation ecosystem and digital transformation, encompassing technology adoption, investment, and government support is sufficiently robust. However, it must still be matched by stronger digital well-being and social connectivity (PC1) to advance its digital readiness fully. The country with the lowest PC1 value is Ethiopia (code 101, low-income), reflecting very low digital well-being and social connectivity. In contrast, the country with the lowest PC2 value is Greece (code 15, high-income), reflecting very low readiness in its innovation ecosystem and digital transformation.

The model yields a strong overall R^2 of 0.9885, meaning 98.85 percent of the variance in economic growth (GDP) is explained by the model's variables, with all variables significant at the 1%–5% level (see Table 5). The variables GCF (public investment), LF (labor force), inflcpi (inflation), and GE (government spending) have a significant positive effect on growth, while EDC (minimum educational attainment of a bachelor's degree) significantly reduces it; digital readiness (NRI) significantly boosts growth across all income groups. Overall, these results are consistent with conventional macroeconomic theory: capital accumulation, labor mobilization, and government expenditure remain fundamental engines of growth, while the negative coefficient on tertiary education attainment points to a structural misalignment between educational output and productive labor market absorption across the 105 countries studied.

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Table 5. Regression Results (NRI on Economic Growth)

Dependent variable (lnGDP)	Coefficient
lnGCF	0.2942716***
lnLF	0.2644497***
lnflcpi	0.0010399***
lnGE	0.4605597***
edc	-0.0048649***
lnNRI	0.0018956**
DhNRI	0.6167026***
DmNRI	0.3020364***
Constant	2.976305***
R-squared	**0.9885**
Prob > chi2	**0.0000**

Note: ***Significant at the 1% significance level; **Significant at the 5% significance level; *Significant at the 10% significance level

Given its positive sign, the level of investment should indeed boost economic growth. From the equation above, if public investment increases by 1%, economic growth will increase by 0.294%. Furthermore, Okun's Law, which assumes that the unemployment rate can be used as a proxy for the labor force (LF) employed in the economy, has a negative relationship with real GDP; thus, the labor force (LF) has a positive relationship with real GDP (Bod'a et al., 2006). The regression results indicate that a 1% increase in the labor force is associated with a 0.264% increase in economic growth.

The inflation variable has a significant positive effect, indicating that higher inflation is associated with greater economic growth. Keynesian theory explains that in the short term, an aggregate rise in prices will increase output and boost economic growth; however, in the long term, high inflation rates will cause a decline in purchasing power, leading to a decrease in aggregate consumption, as well as reduced investment and government spending, thereby lowering economic growth. The regression results indicate that a 1% increase in inflation will raise economic growth by 0.1%. The government spending variable has a significant positive relationship with economic growth. This aligns with Keynesian theory, which states that government spending plays a crucial role in stimulating economic activity by increasing public spending to stimulate demand, create jobs, and drive economic growth (Wahyudi, 2020). The regression results indicate that if government spending increases by 1%, economic growth will rise by 0.46%.

The variable representing the minimum educational attainment level of a bachelor's degree or equivalent has a significant negative impact on economic growth. The regression results indicate that if the minimum educational attainment level, such as a bachelor's degree or equivalent, increases by 1%, economic growth will decrease by 0.5%. An increase in the number of college graduates does not automatically boost economic growth. Research conducted by Neycheva (2019) indicates that a high proportion of college graduates, coupled with insufficient job availability, leads to an oversupply of educated labor and negatively

impacts economic growth. Siyi Gu (2024), through a comparative study in China, Germany, and the United States, demonstrates that higher education has a complex impact on economic growth. In China, for example, the rapid expansion of higher education has created challenges such as a talent mismatch, which can hinder economic growth. The mismatch between educational output and labor market needs, coupled with an oversupply of graduates, actually suppresses economic growth. A study of 78 countries indicates that quantitative expansion of higher education without improvements in quality and relevance can negatively impact economic growth, particularly in developing countries (Hemmati, 2020).

The effect of the NRI variable (digital readiness) on the three income groups of countries, when analyzed alongside its dummy variables, was found to be significant and positive across high-, middle-, and low-income countries. In high-income countries, the NRI significantly boosts economic growth; a one-point increase in the NRI index raises economic growth by up to 61.9% (the sum of the NRI coefficient's elasticity and the DhNRI coefficient). In middle-income countries, the NRI has a significant positive effect; a 1-point increase in the NRI index boosts economic growth by 30.4% (the sum of the NRI coefficient and the DmNRI coefficient), and in low-income countries, it increases by 0.2% (only the NRI coefficient's elasticity, as Dh and Dm are zero). The stark income gradient, where the NRI effect in high-income countries is approximately 310 times that in low-income countries, reflects the role of complementary factors such as advanced digital infrastructure, strong institutions, deep financial systems, and a skilled labor force in amplifying the economic returns to digital readiness; this underscores that digital readiness alone is necessary but not sufficient for growth in resource-constrained settings

The findings of this study indicate a shift in results from a previous study by Yugo (2020), which examined the relationship between the digital readiness index and its impact on economic growth, unemployment, and labor absorption using data from 2013–2016. That study concluded that the digital readiness index (NRI) has a positive impact only in high-income countries, but has a negative impact in middle- and low-income countries. This difference can be explained by the updated data period and current post-pandemic conditions, where the adoption of digital technology has become increasingly widespread and equitable, even in middle- and low-income countries. The analysis period in this study (2019–2023) captures the broader phenomenon of digital transformation, including increased investment in digital infrastructure, internet penetration, and technology adoption by economic actors. These results reinforce Solow's growth theory, which holds that technological change can enhance labor productivity and long-run economic growth. Thus, this study offers a new contribution to the literature by demonstrating that digital readiness has now become a relevant growth driver across all income groups of countries, in line with the increasing access to and penetration of digital technology in recent years.

Interestingly, not all prior evidence points in the same direction regarding which income group benefits most from ICT. Appiah-Otoo & Song (2021) found that while ICT increases economic growth in both rich and poor countries, poor countries (middle- and low-income) tend to gain more from the ICT revolution. This contrasts with the present study's finding that the NRI effect is strongest in high-income countries. Habibi & Zabardast (2020) similarly found a positive association between ICT and economic

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growth in both Middle Eastern and OECD countries. Furthermore, Nguyen (2021) found that digitalization and governance each independently promote economic growth; however, their interaction significantly impedes it, indicating that in developing countries with poor institutional quality, government restrictions on digital platforms tend to limit the growth-enhancing potential of digitalization. This dynamic helps explain the weaker NRI growth effect observed in low-income countries in the present study.

A broader body of cross-national panel evidence further supports the income-differentiated pattern of NRI effects on economic growth. Farhadi et al. (2012) found a consistently positive and significant relationship between ICT and economic growth across all income groups. Critically, their income-stratified estimates revealed that the ICT coefficient was highest for the high-income group (0.11) and progressively declined to 0.09 for upper-middle, 0.06 for lower-middle, and only 0.02 for low-income countries, which means that a 1% improvement in ICT use raises a high-income country's GDP per capita by 5.5 times that of a low-income country. This income gradient directly parallels the present study's finding that the NRI raises economic growth by 61.9% in high-income countries compared to just 0.2% in low-income countries. Cheng et al. (2021) found that ICT diffusion positively and significantly improves economic growth only in high-income countries. This directly reinforces the present study's finding that the NRI's growth effect is strongest in high-income countries. From a regional perspective, Sassi and Goaied (2013) found a positive and significant direct effect of ICT on economic growth. They identified that the interaction between ICT penetration and financial development is also positive and significant.

Principal Component Analysis (PCA) of the 46 indicator variables comprising the NRI yielded three new variables (principal components) that accounted for 60.90% of the total variance, indicating that just these three derived variables can explain the Digital Readiness Index (NRI). The three new variables formed by the PCA analysis are PC1 (Digital Well-being and Social Connectivity), PC2 (Innovation Ecosystem and Digital Transformation), and PC3 (Technology Infrastructure and Digital Economy). These three variables are the factors that most influence the NRI index. The results of the scoreplot analysis illustrate the digital readiness of 105 countries. PCA analysis confirms that high-income countries rank higher on the Digital Readiness Index in nearly all aspects (all indicators). The country with the lowest PC1 score is Ethiopia (in the low-income country category), indicating very low scores for Digital Well-being and Social Connectivity. Meanwhile, the country with the lowest PC2 score is Greece (in the high-income category), indicating a very low score for the Digital Innovation and Transformation Ecosystem. Indonesia itself is in Quadrant IV, meaning it has a fairly good PC2 score (Digital Innovation and Transformation Ecosystem) (> 0), but a poor PC1 score (Digital Well-being and Social Connectivity) (< 0).

CONCLUSION

The relationship between the Digital Readiness Index (NRI) and economic growth indicates that digital readiness significantly boosts GDP across all income groups, with the greatest impact in high-income countries (61.9%), followed by middle-income countries

(30.4%) and low-income countries (0.2%). Digital readiness has become a relevant driver of economic growth, in line with the increasing access to and adoption of digital technology in recent years.

Governments and policymakers should therefore implement strategies tailored to the income level. (1) High-income countries, which already have strong digital readiness, should sustain and enhance their position by investing in emerging technologies such as AI, IoT, and 5G, strengthening innovation ecosystems, maintaining data security and privacy, and ensuring inclusive digital programs so all societal segments benefit. (2) Middle- and low-income countries require targeted measures: (a) increasing investment in ICT infrastructure to ensure equitable, reliable broadband access, including in rural and underserved areas; (b) expanding adoption of high-tech solutions through domestic R&D and technology transfer from developed countries to foster innovation and productivity; and (c) strengthening workforce skills through formal and informal education aligned with labor market needs, including digital literacy, coding, and digital entrepreneurship training. These strategies would allow governments across income groups to leverage digital readiness as a sustainable driver of growth while reducing digital inequalities and ensuring inclusive participation in the global digital economy.

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Poverty and Economic Growth: The Socioeconomic Determinants of Stunting Prevalence in Indonesia

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ABSTRACT

Research Originality: This study provides recent provincial evidence from Indonesia (2010–2024) on the nexus between poverty, economic growth, and stunting.

Research Objectives: This study aims to investigate the effects of poverty and economic growth on stunting prevalence in Indonesia, using parental education level and the open unemployment rate as proxies.

Research Methods: This study employs path analysis using a natural-log approach and analyzes data from 2000 to 2023. Key variables include socioeconomic determinants and stunting prevalence.

Empirical Results: The findings of this study include: poverty has a negative and significant effect on parental education and open unemployment, while economic growth has no significant effect on parental education and open unemployment; poverty affects the prevalence of stunting through parental education and open unemployment, while economic growth does not affect the prevalence of stunting through parental education and open unemployment.

Implications: The findings suggest that reducing stunting requires inclusive economic growth and effective poverty alleviation. Therefore, policies should focus on strengthening social protection and improving access to nutrition and health services.

Keywords:

parental education level; open unemployment rate; path analysis; child health; social problem

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INTRODUCTION

Stunting remains one of the most persistent public health and human development challenges in Indonesia (Beal et al., 2018). Most provinces in Indonesia have been in a moderate prevalence of stunting from 2021, 2022, and 2024, namely 20%-29.9%. Data from 2024 shows that several provinces have high stunting prevalence rates, particularly in the eastern region, namely West Sulawesi (35.4%), Central Papua (32.5%), Southwest Papua (30.5%), East Nusa Tenggara (37%), and the province with the very high status is Mountainous Papua (40%). Provinces in the low category are South Sumatra (15.9%), Lampung (15.9%), Riau Islands (15%), North Kalimantan (17.6%), East Java (14.7%), Central Java (17.1%), West Java (15.9%), Jambi (17.1%), DKI Jakarta (17.3%), DI Yogyakarta (17.4%), Bengkulu (18.8%), and Bali (8.7%) (Astuti et al., 2025).

In Indonesia, Beal et.al. (2018) found that community and societal factors, particularly poor access to health services and living in rural areas, have been repeatedly linked to child stunting. Households living below the poverty line generally experience limited access to nutritious food, healthcare services, sanitation facilities, and educational opportunities, thereby increasing children's vulnerability to growth failure (Handoko et al., 2024; Mudd et al., 2021; Widyaningsih et al., 2022). Handoko et al. (2024) and Widyaningsih et al. (2022) found that children from low-income households and rural communities consistently have a higher risk of stunting than those from wealthier households and urban areas. Socioeconomic inequality, therefore, plays a crucial role in shaping nutritional outcomes among children. In Ethiopia, Gebregergis (2024) found that, despite a notable decline in the average rates of stunting and underweight prevalence, the relative and absolute gaps between different demographic and socioeconomic groups have widened. This finding confirmed that higher levels of maternal education and household wealth significantly benefited children from better socioeconomic backgrounds, reducing their risk of malnutrition. Socioeconomic disparities are the primary driver of inequality in child malnutrition. These findings are consistent with studies by (Wand et al., 2024), in South Africa (Saidu & Danielson, 2024), (Ijaiya et al., 2024), and (Kalinda et al., 2023)

According to Ayue et al. (2025) and Mary (2018), economic growth is theoretically expected to improve household welfare and reduce malnutrition by increasing income, expanding employment opportunities, and enhancing government capacity to provide social services. However, according to Soriano and Garrido (2016), the relationship between economic growth and stunting remains inconclusive. In Bangladesh, Yaya et al. (2020) found no significant association between economic growth and child nutritional status in developing countries. The prevalence of stunting decreased with increasing GDP per capita. This was more pronounced among children from the richest quintile. The magnitude of the association was higher among children from low-income countries, suggesting that households in the poorest quintile were typically the least likely to benefit from economic gains.

The findings could serve as a building block needed by Suparman and Muzakir (2023) and Yang et al. (2024) because, consequently, provinces experiencing high economic

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growth may still exhibit high stunting prevalence when growth is not accompanied by inclusive development and improvements in human capital (Alemu et al., 2025; Aswi et al., 2025; Olakunle, 2024; Rogna, 2024). Kustanto (2021) found that empirical evidence from Indonesia indicates a dynamic relationship between economic growth, poverty, and stunting, suggesting that economic performance alone is insufficient to eliminate chronic malnutrition.

Beyond poverty and economic growth, several socioeconomic determinants have been recognized as important factors influencing stunting prevalence by Ariet et al. (2025). Previous studies have highlighted the significance of parental education, employment status, household socioeconomic conditions, access to healthcare, sanitation, and residential location (Arief et al., 2025; Baliwati & Rusyda, 2025; Siramaneerat et al., 2024). Higher parental education is associated with improved nutritional knowledge and childcare practices, whereas unemployment and socioeconomic deprivation limit households' capacity to provide adequate nutrition and health services (Ayue et al., 2025; Siramaneerat et al., 2024). These findings support the view that stunting should be examined through a multidimensional socioeconomic framework rather than a purely health-oriented perspective (Beal et al., 2018).

Higher parental education is associated with improved nutritional knowledge and childcare practices, whereas unemployment and socioeconomic deprivation limit households' capacity to provide adequate nutrition and health services (Ijaiya et al., 2024; Siramaneerat et al., 2024). The prevalence of stunting is commonly used as an indicator of community nutritional status and broader socioeconomic deprivation (Siramaneerat et al., 2024). A high prevalence of stunting often reflects broader structural development problems, such as poverty, inadequate water and sanitation infrastructure, limited access to education, and poor healthcare services (Cameron et al., 2021). The long-term consequences of stunting include lower cognitive performance, diminished human capital, and a higher risk of disease and premature mortality (Suparman & Muzakir, 2023). Galasso and Wagstaff (2019) state that stunting adversely affects individual productivity and human capital formation, which collectively may reduce national economic growth and GDP over time.

Worker productivity plays a fundamental role in generating national income and supporting government fiscal capacity through increased economic output and tax revenues. This is the source of the nation's economic revenue, derived from converting worker productivity into government spending (Hornok & Raeskyesa, 2024). Stunting is the cause of this. contribute to the high costs in the medical field, especially those driven by stunted conditions (Hamzah et al., 2025; Saidu & Danielson, 2024). Those who suffer from this are more likely to experience degenerative illnesses or may pass away too soon. Data on national stunting, its causes, and its effects are intimately related to this study (Kustanto, 2021). This study examines how poverty and economic growth, as mediated by parental education and open unemployment, affect the prevalence of stunting in Indonesia between 2000 and 2023, using the natural logarithm.

Beal et al. (2018) showed that child stunting in Indonesia is closely related to limited access to health services and rural conditions. Meanwhile, Gebregergis (2024) found that

although the prevalence of stunting and underweight in Ethiopia declined, disparities between socioeconomic groups actually increased. Higher maternal education and better household welfare levels have been shown to reduce the risk of child malnutrition, making socioeconomic inequality a major factor causing nutritional disparities. These findings align with research by Wang et al. (2024), Saidu and Danielson (2024), Ijaiya et al. (2024), and Kalinda et al. (2023).

Despite the extensive literature on stunting in Indonesia, research has largely focused on household and child-level determinants, with limited attention to the combined influence of macroeconomic and socioeconomic factors (Anita Kartika Putri & Ida Budiarty, 2026; Kustanto, 2021a; Lumbantoruan & Azansyah, 2024; Yaya et al., 2020). Studies by Kustanto (2021) and Beal et al. (2018) emphasize that, moreover, poverty and economic growth are often examined separately, and few studies have integrated poverty, economic growth, unemployment, and parental education within a single framework to explain provincial variations in stunting prevalence.

Addressing this gap, this study develops an integrative socioeconomic model that simultaneously analyzes the direct and indirect effects of economic growth, poverty, unemployment, and parental education on stunting prevalence in Indonesia. The novelty of this research lies in its examination of parental education and unemployment as mediating pathways linking economic conditions to stunting outcomes. Accordingly, this study aims to investigate the effects of poverty and economic growth on parental education and unemployment, and their direct and indirect impacts on stunting prevalence across Indonesian provinces. The findings are expected to enrich the literature on public health and development economics while providing evidence-based policy recommendations for accelerating stunting reduction through inclusive socioeconomic development.

METHODS

This study covers 34 provinces in Indonesia, and most provinces are in moderate stunting prevalence, with rates of 20% - 29.9% in 2021, 2022, and 2024. Similarly, areas with low poverty rates are mostly located in western Indonesia. Various factors influence the prevalence of stunting, including unemployment, parental education, poverty, and economic growth (Arief et al., 2025). Secondary data were used in this study. The panel data comprises 34 Indonesian provinces over 24 years (2000-2023). The data were obtained from various sources, including the Central Bureau of Statistics (BPS) and the United Nations Children's Fund (UNICEF). Table 1 presents the more detailed information about the operational variables.

Path analysis using natural-log data will reduce bias due to unequal variable measurements (Jinuntuya & Jinuntuya, 2025). Minimal interval measurement scale, additive qualities, causal links, recursiveness, and linear relationships among variables are among the assumptions of path analysis (Sarstedt et al., 2021). Based on previous research, the conceptual framework of this research is as follows, in Figure 1.

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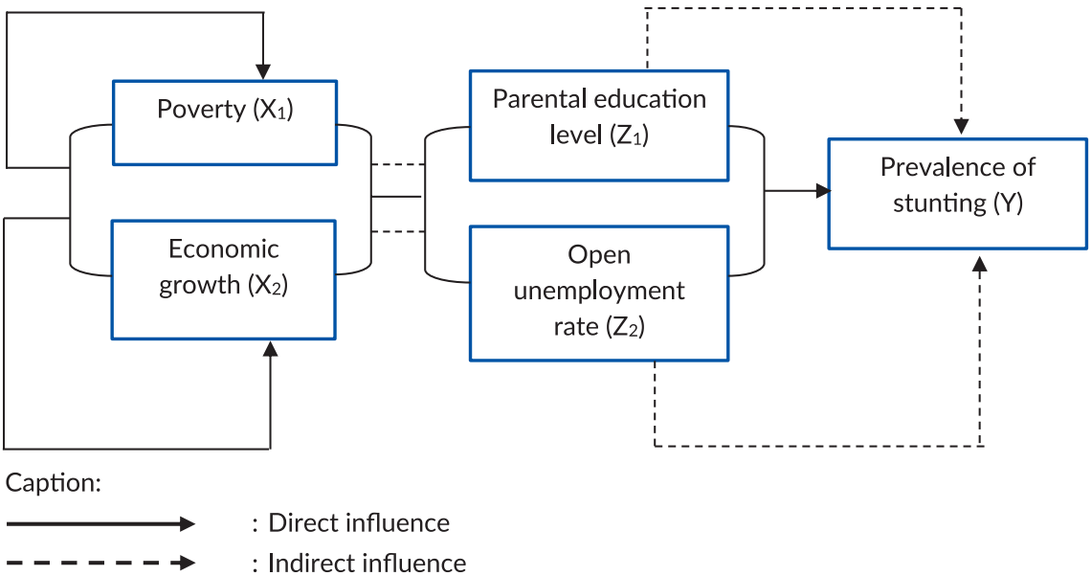
Table 1. Operational Variables

Variables	Definitions	Measurements	Sources	References
Poverty	Proportion of the population living below the poverty line	Poverty rate (%)	BPS	(Wang et al., 2024)
Economic Growth	Indicator of economic performance and its potential to reduce the prevalence of stunting (GRDP)	GRDP per capita (%)	BPS	(Haider et al., 2023; Matovu et al., 2026)
Parental Education Rate	The highest level of education, defined as the level of education completed by the parent during their education	People (soul)	BPS	(Supadmi et al., 2024)
Open Unemployment Rate	The percentage of the number of unemployed to the total workforce	proportion of unemployment rate (%)	BPS	(Apriyanti & Yanuarti, 2024)
Prevalency Stunting	The nutritional status of children less than five years of age was measured anthropometrically	The percentage of the stunting rate	Riskeda, SSGBI	(Siramaneerat et al., 2024; Ssentongo et al., 2021)

Figure 1. Conceptual Framework



The formulation of the path analysis model is as follows:

1. The influence of poverty and economic growth on parental education levels

$$Z1 = \beta 1\ X1 + \beta 2\ X2 + \varepsilon i \quad (1)$$

which: Z1 is parental education level, X1 is poverty, X2 is economic growth, β1 and β2 are the coefficients of the path, and εi is the standard error.

2. The influence of poverty, economic growth, parental education level, and open unemployment rate on the open unemployment rate

$$Z2 = \beta 3\ X1 + \beta 4\ X2 + \epsilon i \quad (2)$$

which: Z2 is the open unemployment rate, X1 is poverty, X2 is economic growth, β3 and β4 are the coefficients of the path, and εi is the standard error.

3. The influence of poverty, economic growth, parental education level, and open unemployment rate on the prevalence of stunting

$$Y = \beta 5\ X1 + \beta 6\ X2 + \beta 7\ Z1 + \beta 8\ Z2 + \epsilon i \quad (3)$$

which: Y is stunting prevalence, X1 is poverty, X2 is economic growth.

4. The influence of poverty and economic growth on the prevalence of stunting through parental education level

$$Y = \alpha 1\ X1 + \alpha 2\ X2 + \alpha 3\ Z1 + \epsilon i \quad (4)$$

Which: Y is stunting prevalence, X1 is poverty, X2 is economic growth, and Z1 is parental education level.

5. The influence of poverty and economic growth on the prevalence of stunting through the unemployment rate.

$$Y = \alpha 4\ X1 + \alpha 5\ X2 + \alpha 6\ Z2 + \epsilon i \quad (5)$$

Which: Y is stunting prevalence, X1 is poverty, X2 is economic growth, and Z2 is open unemployment rate.

RESULTS AND DISCUSSION

Table 2 presents the descriptive statistics for the variables used in the analysis, all of which are natural logarithms. The average stunting prevalence is 3.5096 with a standard deviation of 0.1977, indicating relatively low variation across provinces. Parental education has a mean of 2.0659 and a standard deviation of 0.0988, suggesting a highly homogeneous distribution. The open unemployment rate has an average of 1.9541 and a standard deviation of 0.2343, indicating moderate variation across observations. Poverty has a mean value of 2.5590 and a standard deviation of 0.2532, reflecting noticeable disparities across provinces. Economic growth shows an average of 1.5680 and the highest standard deviation (0.3625), indicating greater heterogeneity in regional economic performance. Overall, stunting prevalence and parental education exhibit relatively low variability, whereas poverty and economic growth show greater variation across provinces.

Table 2. Summary Statistics

Variables	N	Mean	Std. Dev.	Min	Max
Prevalence Stunting	24	3.5096	0.1977	3.0681	3.7471
Parental Education Level	24	2.0659	0.0988	1.9021	2.2192
Open Unemployment Rate	24	1.9541	0.2343	1.6544	2.4195
Poverty	24	2.5590	0.2532	2.2214	2.9518
Economic Growth	24	1.5680	0.3625	0.0000	1.8485
Valid N (listwise)	24				

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Before conducting the path analysis, several assumptions were tested. First, the One-Sample Kolmogorov-Smirnov (K-S) test was used to assess the normality of the data. As shown in Table 3, all variables have p-values greater than 0.05, indicating that the data are normally distributed and satisfy the assumption of normality (Jinuntuya & Jinuntuya, 2025). Second, multicollinearity was examined to identify potential high correlations among the independent variables. The results indicate that economic growth, poverty, open unemployment, and parental education do not exhibit multicollinearity, confirming that the regression model meets the required assumption (Harvey et al., 2022; Selvanus et al., 2024).

Third, Table 4 shows that the results of the path coefficient linearity test are linear, because the p-value is greater than the significance level (α) of 5%. This indicates that all relationships between exogenous and endogenous variables are linear. The additive assumption indicates that the influence of variables poverty, economic growth, parental education level, and open unemployment rate on prevalence is assumed to work independently, and their contributions to prevalence stunting can be assumed linearly (Alemu et al., 2025; Apriyanti & Yanuarti, 2024; Ijaiya et al., 2024).

Table 3. Normality Test, Autocorrelation, and Collinearity Test

Variable	K-S Statistic	Asymp. Sig.	Information	Tol	VIF
Prevalence Stunting	0,271	0,090	Normal		
Parental Education Level	0,077	0,200	Normal	0,038	26,341
Open Unemployment Rate	0,173	0,062	Normal	0,281	3,560
Poverty	0,152	0,161	Normal	0,029	34,062
Economic Growth	0,305	0,070	Normal	0,888	1,126

Durbin-Watson = 1.907
Note: Dependent Variable Prevalence Stunting

Path analysis was employed to examine the direct and indirect effects of poverty and economic growth on stunting prevalence, with parental education and the open unemployment rate serving as mediating variables (Putri & Budiarty, 2026). Previous studies have shown that poverty significantly influences educational attainment, highlighting the importance of integrated policies to improve educational outcomes among disadvantaged populations (Sosu et al., 2026). Evidence also suggests a strong relationship between poverty and parental education, particularly among women (Kalinda et al., 2023; Momo et al., 2021; Wu et al., 2022). Furthermore, education and economic growth are closely interconnected and play important roles in poverty reduction, underscoring the need for policies that strengthen parental education (Li et al., 2024; Wu et al., 2022). The results of the path analysis for the model are presented in Table 5.

Table 5 presents the path analysis results for Models 1-5. Model 1 indicates that poverty has a significant negative effect on parental education, whereas economic growth has a negative but insignificant effect. These findings suggest that poverty is a more important determinant of parental education than economic growth in Indonesia. The F-test further indicates that variations in poverty and economic growth across provinces

should be taken into account when formulating educational policies. The insignificant effect of economic growth may reflect persistent income-distribution inequalities, limited access to education, and the prioritization of basic household needs. Therefore, integrated policies that address poverty and educational access are essential to achieving SDG 4 (Quality Education) and SDG 8 (Decent Work and Economic Growth) (Carneiro et al., 2025; Mauro, 2025; Momo et al., 2021; Otten & Ha, 2024).

Table 4 . Linearity Test of Path Coefficients

Correlation between variables	β	Correlation
Poverty to parental education level	-0.965	Linear
Economic growth and parental education level	-0.060	Linear
Poverty to open unemployment rate	0.830	Linear
Economic growth to open unemployment rate	-0.123	Linear
Parental Education Level to Prevalence of Stunting	0.733	Linear
Open unemployment rate to the prevalence of stunting	0.209	Linear

Table 5. Coefficient Regression and Model Summary

Model	Variable	Beta (Standardize)	P-Value
1	Poverty	-0.965	.000
	Economic Growth	-0.060	.212
	R = 0.977; R Square = 0.955; Adjusted R Square = 0.951; F-test = 224.074; Sig = 0.000 Note: Dependent Variable Parental Education Level		
2	Poverty	0.830	0.000
	Economic Growth	-0.123	0.347
	R = 0.818; R square = 0.669; Adjusted R square= 0.637; F-test=21.205; sig=0.000 Note: Dependent Variable Open Unemployment Rate		
3	Poverty	-1.492	0.007
	Economic Growth	0.074	0.421
	Parental education level	0.022	0.031
	Open Unemployment rate	-2.287	0.000
	R = 0.930; R square = 0.865; Adjusted R square= 0.836 Note: Dependent Variable Prevalence Stunting		
4	Poverty	-1.451	0.001
	Economic Growth	0.072	0.414
	Parental education level	-2.264	0.000
	R = 0.930; R square = 0.864; Adjusted R square= 0.844; F-test = 42.517; sig = 0.000 Note: Dependent Variable Prevalence Stunting		
5	Poverty	-0.987	0.000
	Economic Growth	0.172	0.215
	Open Unemployment	-0.306	0.039
	R = 0.816; R square = 0.666; Adjusted R square= 0.616; F-test = 13.293; sig = 0.000 Note: Dependent Variable Prevalence Stunting		

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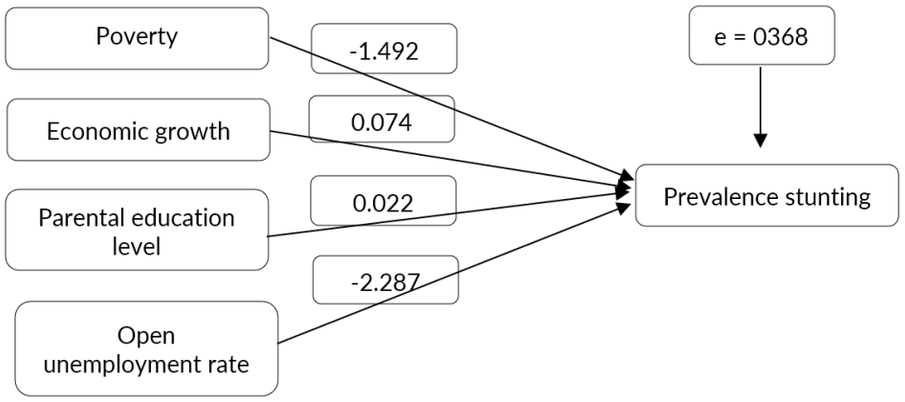
Model 2 shows that poverty has a positive and significant effect on the open unemployment rate, while economic growth has an insignificant effect. This indicates that higher poverty levels tend to increase unemployment, highlighting the need for pro-poor policies to reduce poverty and improve employment opportunities. The insignificant effect of economic growth suggests that economic expansion does not automatically generate jobs. This may occur because growth is concentrated in capital-intensive sectors, labor market skill mismatches, demographic pressures, structural economic changes, productivity-oriented business strategies, and inflationary conditions (Brychka et al., 2023; Dwiningwarni et al., 2019; Kawashita & Marseto, 2024).

Model 3 indicates that poverty has a positive and significant effect on stunting prevalence, while parental education has a significant negative effect, and open unemployment also has a significant effect. In contrast, economic growth has no significant effect. These findings suggest that higher poverty levels increase the risk of stunting, whereas higher parental education reduces it, consistent with previous studies (Jumhur, 2024; Kustanto, 2021a; Mulyaningsih et al., 2021a). The insignificant effect of economic growth implies that economic expansion alone is insufficient to reduce stunting, particularly when its benefits are unevenly distributed and not accompanied by improvements in nutrition, sanitation, healthcare access, and human capital development. Therefore, investments in education and health remain essential for accelerating stunting reduction and achieving the SDGs related to poverty alleviation and public health (Choi & Min, 2024; Mauro, 2025; Yaya et al., 2020). From model 3, the structure of path analysis 3 is shown in Figure 2.

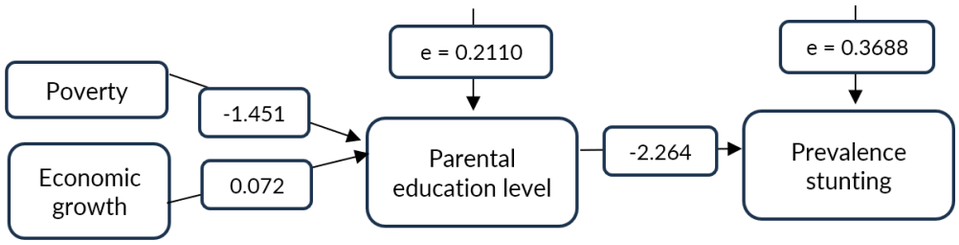
Figure 2. Structure of path analysis-3



Model 4 shows that poverty significantly affects stunting prevalence through parental education, indicating that low-income households tend to have lower educational attainment, limited access to health services, and a higher risk of stunting. This finding supports previous studies emphasizing the role of parental education in linking poverty to child nutritional outcomes (Jamil et al., 2022; Oriaku Emordi, 2024; Wang et al., 2024). In contrast, the indirect effect of economic growth on stunting through

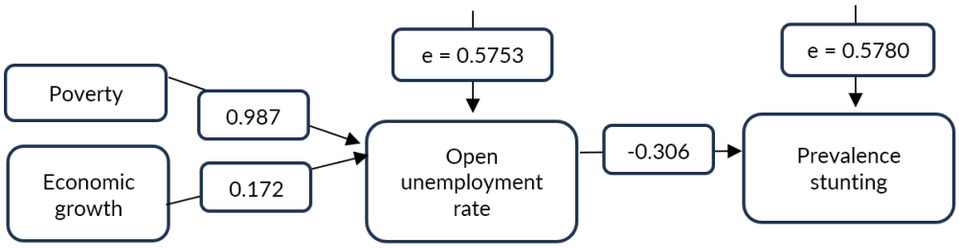
parental education is not significant, suggesting that economic growth has not sufficiently improved educational quality or reduced the prevalence of stunting. This may reflect persistent inequalities in income distribution, nutrition, sanitation, and parenting practices. Therefore, integrated policies that simultaneously promote economic growth, educational improvement, and nutritional well-being are essential for sustainable stunting reduction (Elmira & Qaim, 2026; Jumhur, 2024; Kustanto, 2021). From model 4, the structure of path analysis 4 is presented in Figure 3.

Figure 3. Structure of path analysis-4



Model 5 shows that poverty significantly affects stunting prevalence through the open unemployment rate, indicating that higher poverty increases unemployment, which in turn raises the risk of stunting (Aureli & Juliprijanto, 2022; Laksono et al., 2022; Puja Ilham, 2023; Supadmi et al., 2024b; Suparman & Muzakir, 2023). In contrast, Margettyaningsih et al. (2024) state that the indirect effect of economic growth on stunting through unemployment is not significant, suggesting that economic growth has not generated sufficient employment opportunities to reduce poverty and stunting. These findings imply that the benefits of economic growth have not been fully experienced by low-income households, resulting in persistent poverty and stunting despite economic expansion. However, these results differ from those reported by Purba et al. (2024) and Kirana & Nilasari (2025). From model 4, the structure of path analysis 4 is shown in Figure 4.

Figure 4. Structure of path analysis-5



Kustanto's (2021) research shows that the prevalence of stunting is directly related to poverty and long-term economic growth. Higher levels of formal education of mothers and fathers will reduce the rate of child stunting in rural and urban areas. Research by Mergettyaningsih, Suryanto, and Gravitiani (2024) showed that GDP per capita and

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poverty had a positive and significant effect on the prevalence of stunting, while literacy, sanitation, and HDI had a negative effect. Research by Mulyaningsih et al. (2021) states that several factors influence stunting, namely eating habits, newborn weight, history of infection, gender, family income, parental education level, and environmental factors related to access to water, sanitation, and hygiene.

Table 7. Direct, Indirect, and Total Effect

Correlation	Direct Effect	Indirect Effect	Total Effect
Poverty to Parental Education Level	-0.965		
Economic Growth to Parental Education Level	-0.060		
Poverty to Open Unemployment Rate	0.830		
Economic Growth to Open Unemployment Rate	-0.123		
Poverty and Economic Growth to the Prevalence of Stunting	0.733		
Economic Growth to Prevalence of Stunting	0.133		
Poverty to Prevalence of Stunting through Parental Education Level		-1.6595	-3.1105
Economic Growth to Prevalence of Stunting through Parental Education Level		-0.1630	-0.0910
Poverty to Prevalence of Stunting through Open Unemployment Rate		-0.3020	-0.1300
Economic Growth to Prevalence of Stunting through Open Unemployment Rate		-0.0526	0.9344

The actual impacts of the path analysis used in this study, namely direct, indirect, and total effects, are shown in Table 7. Parental education emerges as the most influential mediator linking poverty to stunting prevalence, indicating that improvements in parental education can substantially reduce the impact of poverty on child nutritional outcomes. While parental education also strengthens the contribution of economic growth to stunting reduction, the mediating role of open unemployment is relatively weaker. Moreover, despite its negative effect on unemployment, economic growth has a positive overall effect on stunting prevalence, suggesting that economic expansion alone is insufficient to reduce stunting rates without parallel improvements in education and broader socioeconomic conditions. The results of the study indicate that poverty is a major determinant influencing stunting prevalence, both directly and indirectly. Among the mediating variables, parental education level showed a stronger mediating effect than open unemployment. These findings indicate that stunting reduction policies need to focus not only on reducing poverty levels but also on improving access to and the quality of parental education as a long-term strategy to improve children's nutritional status and reduce stunting prevalence in Indonesia.

CONCLUSION

Indonesia's stunting situation requires significant attention. Path analysis results show that poverty continues to strongly influence stunting prevalence, whereas economic growth has no significant effect. This situation is driven by persistent poverty during the period 2000-2023. The findings indicate that poverty significantly affects stunting prevalence both directly and indirectly through parental education and open unemployment. In contrast, economic growth does not significantly influence stunting prevalence, parental education, or open unemployment. These results suggest that stunting in Indonesia is primarily a socioeconomic issue linked to household deprivation, limited educational attainment, and labor market vulnerability rather than merely a consequence of low economic growth.

Based on these findings, policy interventions should prioritize targeted poverty reduction among households with pregnant women and children under five through strengthened social protection programs, nutrition-sensitive cash transfers, and improved access to health and nutrition services. In addition, the government should expand parental education and nutrition literacy programs while promoting employment opportunities through labor-intensive industries and vocational training targeted at low-income populations. Since economic growth alone has not translated into lower stunting prevalence, national stunting reduction strategies should focus on inclusive development by integrating indicators of multidimensional poverty, educational attainment, and employment into policy design, implementation, and evaluation, and be supported by regular socioeconomic mapping of vulnerable households to improve targeting effectiveness.

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Economic Growth Mediates the Effects of Socioeconomic Factors and Reduces Stunting in Indonesia

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ABSTRACT

Research Originality: This study offers original insights by examining the multifactorial determinants of stunting in Indonesia, with particular focus on the roles of social food assistance, food insecurity, public literacy, unemployment, and economic productivity within a panel data framework.

Research Objectives: This study aimed to analyze the effects of social food assistance, food insecurity, public literacy, unemployment, and economic productivity on the prevalence of stunting in Indonesia.

Research Methods: This study employs a quantitative approach using panel data for 34 Indonesian provinces from 2018 to 2022. The analysis used regression models to evaluate both direct and indirect relationships among the variables.

Empirical Results: The findings indicate that literacy, social food assistance, food security, and economic growth significantly reduce stunting rates. Unemployment does not directly affect stunting, but it does so indirectly through its impact on economic growth. Additionally, literacy, food assistance, and food security positively affect economic growth, whereas unemployment has a minimal direct impact. Economic growth is an important mediating variable for reducing stunting.

Implications: These results suggest that reducing stunting in Indonesia requires integrated policies that combine social food assistance with improvements in literacy, food security, and economic development. Policymakers should prioritize cross-sectoral strategies, including nutrition education and economic empowerment, to effectively address stunting.

Keywords:
economy; food security; literacy; stunting; unemployment

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INTRODUCTION

Human capital is an essential component of any economy. Human resources must be well-nourished to be practical. However, many communities fall short of meeting these requirements. Malnutrition is common in many population groups in developing countries, and stunting among children below five years of age is a significant concern. Stunting affects the growth and development of children, leading to lower intelligence, increased risk of non-communicable diseases, reduced productivity, and long-term poverty (Vonaesch et al., 2021). In the world, 165 million children below the age of five, which is around 26% of the population, are stunted. Of these, approximately 95.8 million are children from Asia, which comes in second after Africa in terms of stunted children, with a 26.8% prevalence. In Southeast Asia, it is 27.8%, representing approximately 14.8 million children. According to the 2022 report, the highest stunting rate is in Pakistan at 45%, followed by Congo (43%), Ethiopia (38%), India (39%), and Bangladesh (36) %. In contrast, the issue has a low incidence in China, at only 9%. According to WHO, stunting prevalence in Indonesia was 36.5% in 2021, whilst the WHO states the cut-off level is 20% (Wand et al., 2024).

Countries with high stunting challenges witness economic growth, which often correlates with high stunting prevalence. For example, India had a stunting prevalence of 39% in 2021, one of the highest rates, and also recorded slow year-over-year growth of 4.5% in the third quarter. Economic growth for Pakistan also fell from 5.5% the previous year to 3.3% in 2021 (Alderman et al., 2006). Nigeria, which has the third-highest number of stunting cases reported, has an average annual economic growth rate of 5.4%. Indonesia's economy grew by 3.69% in 2021, recovering from a 2.07% decline in 2020. The correlation that exists between stunting as an indicator of health and economic growth is evident. Economic growth helps reduce stunting by raising household incomes, thereby providing the means to access resources such as adequate food, healthcare, and education (Mary, 2018).

Nevertheless, stunting remains widespread in Indonesia, indicating that the public health situation in the country is still not ideal. According to H.L. Blum's theory, health status is determined by four indicators: environment (40%), behavior or lifestyle (30%), healthcare systems (20%), and genetics (10%). These determinants assist in planning effective health interventions (Blum, 1974). Environmental factors include physical, social, and economic factors. Hence, social food security and food assistance fall into this category, as those who are food secure have more resources and can thus reduce their risk of malnutrition. There are also social determinants, such as economic growth and unemployment, that affect the category and the primary focus of health needs (Paul et al., 2019). Behavioral risks, which range from individual actions to choices and decisions, account for 30%. Among the behavioral aspects, literacy comes into play in the area of health decision-making. Literate individuals will be more health-conscious and take precautions to avoid contracting diseases (Hanushek & Woessmann, 2020).

Stunting is affected by household food security. Households that face food insecurity tend to have children who are stunted in growth. There is also a need for a sufficient variety of food, especially for children under 5 years old, during rapid development.

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The Food and Agriculture Organization (FAO's) conceptual framework describes food security in 4 dimensions: availability, access, utilization, and stability, which are factors that affect children's nutritional status. The availability and accessibility of an adequate and nutritious diet are essential to overcoming stunting. The social welfare theory shows how social and economic policies work together to improve well-being (Büttner et al., 2023). The human being Sen stresses goes beyond income or economic growth and is about improving people's abilities to lead healthy and productive lives. Focusing on food resources for social assistance and education, work placement, and other issues such as food security contributes to people's abilities and reduces stunting, promoting economic growth as well. There is evidence that stunting affects physical growth, cognitive development, and future living standards. The socioeconomic variables of social food assistance, literacy, food safety, and unemployment have a substantial impact on the scope of the stunting epidemic. Often offered in the form of cash or food subsidies, social food assistance programs improve the communities' access to nourishing food (Parekh et al., 2020).

Several studies have reported no significant association between social assistance programs and trends in stunting reduction. Community-level interventions such as conditional cash transfers (CCTs) appear to make little to no difference in stunting. In contrast, unconditional cash transfers (UCTs) and food vouchers may have only a potential impact, with findings qualified by low certainty of evidence (Berkowitz et al., 2024; Harper et al., 2023). This persistent ambiguity in the literature reflects a deeper theoretical tension: whether social food assistance operates as an independent driver of child nutrition outcomes or is contingent on broader macroeconomic conditions. Social protection interventions show a stronger nutritional impact when combined with behavior change communication and when they ensure income security sufficient for households to afford a healthy diet, suggesting that the channel through which assistance reaches nutritional outcomes is mediated by the economic context (Ataullahjan et al., 2025).

For mothers, literacy has been seen to help them understand nutritional education and practices. Maternal education has emerged as the strongest and most consistent predictor across all forms of child malnutrition, with children of mothers with no education facing more than twice the likelihood of stunting compared with those with higher-educated mothers (Meriç & Demirci, 2026; Wulandari et al., 2025). However, the relationship is not straightforward. Recent evidence from middle-income countries indicates that maternal knowledge alone is insufficient to explain stunting; it can have a meaningful impact only when food diversity and household food security are adequate, confirming that the effect of information operates through a mechanism strongly mediated by material conditions. This finding challenges the conventional assumption that literacy directly reduces stunting and implies that the protective effect of literacy may be conditional on economic enablers, a pathway that prior studies have rarely tested through formal mediation analysis (Suryaningsih & Qolbiyah, 2023).

Food security is widely regarded as a foundational determinant of child growth, as it increases people's sustainable access to food, reducing malnutrition and, in particular, the risk of stunting. A systematic review of studies conducted in Asia and published

between 2019 and 2023 confirmed that stunting is strongly linked to household food insecurity and poor dietary diversity, with socioeconomic factors and maternal education further moderating these associations Walter De et al., 2023; Fogarty & García, 2025). However, food security is not immune to macroeconomic shocks. FAO's findings indicate that although an increase in per capita income reduces food insecurity in the short term, it does not necessarily produce equivalent long-term reductions in child malnutrition indicators, underscoring the need for integrated analyses that account for the indirect pathways linking economic growth, food access, and nutritional outcomes (UNICEF, 2024). Furthermore, unemployment, by reducing household income and limiting access to resources, may indirectly contribute to stunting. Evidence from Pakistan's subnational analysis confirms that improvements in socioeconomic status and coverage of income support programs targeting females were key factors driving reductions in child stunting. At the same time, poverty and increased food prices remain persistent barriers to accessing nutritious foods (Durao et al., 2020).

Theoretically, economic growth works against stunting for society's welfare. Cross-national analyses of low- and middle-income countries (LMICs) confirm a significant association between per-capita gross domestic product and children's risk of malnutrition, while also highlighting the importance of identifying which contributing factors most broadly enable economic growth to reduce malnutrition (Ataullahjan et al., 2025). The World Bank's Investment Framework for Nutrition 2024 further underscores that both undernutrition and obesity are obstacles to human capital and economic productivity, while every dollar invested in addressing undernutrition is estimated to generate a return of 23 dollars a ratio that suggests economic growth and nutrition outcomes are deeply intertwined rather than independent.

To date, studies have shed light on several aspects, but critical gaps remain. Existing research has examined social food assistance, literacy, food security, and unemployment largely as standalone predictors of stunting without adequately interrogating how these variables interact with economic growth or whether economic growth itself functions as a mediating variable between these determinants and stunting prevalence. The body of investigations that have been carried out tends to treat economic growth either as a background condition or as an outcome, rather than as a structural mediator through which upstream determinants ultimately shape children's nutritional status. This is a critical gap: if stunting is influenced by economic growth, then it is plausible that economic growth mediates the relationship between various determinants, including social food assistance, literacy, and food security, and stunting prevalence. For instance, social food assistance may reduce stunting more effectively when combined with sufficient economic growth, as increased purchasing power and expanded economic activity amplify the nutritional impact of assistance programs. Likewise, high literacy and household food security are more effective at reducing stunting when economic growth translates into expanded access to health services and greater dietary diversity. Simultaneously, the negative impact of unemployment on stunting may be offset by economic growth, which creates employment opportunities and increases household disposable income, enabling families to access

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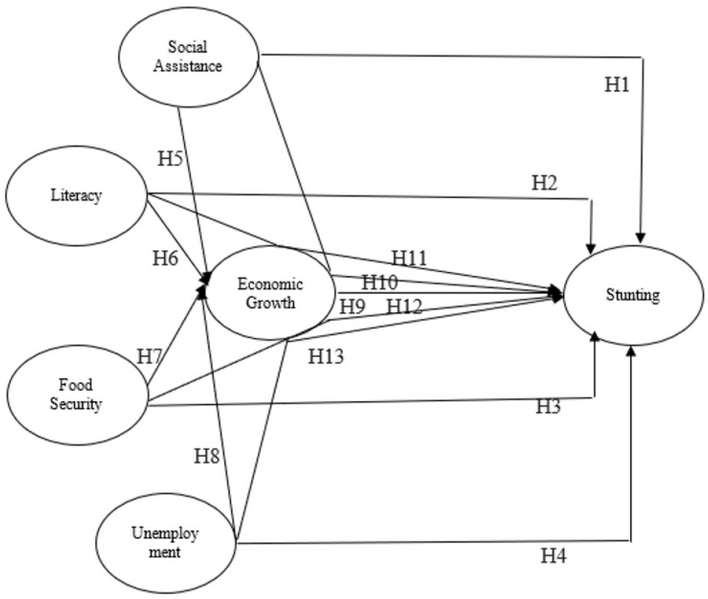
adequate diets. The present study addresses this gap by simultaneously examining literacy, social food assistance, food security, and unemployment as determinants of stunting while testing economic growth as a key mediating variable—an analytical framework that, to the authors' knowledge, has not been previously adopted in the existing literature.

METHODS

This study employs a quantitative research approach to examine the effects of social food assistance, literacy, food security, and unemployment on economic growth and the prevalence of stunting in Indonesia. The analysis uses panel data from 34 provinces during the period 2018–2022. This period was selected because Indonesia had 34 provinces during these years, ensuring consistency and comparability across the panel data. After 2022, the number of provinces increased to 38 following the establishment of new administrative regions, potentially creating structural inconsistencies in the dataset. Therefore, the period 2018–2022 was chosen to maintain data uniformity and analytical reliability. The data used in this research are secondary data obtained from several official government institutions. Data on social food assistance, literacy, food security, unemployment, and other economic indicators were collected from Statistics Indonesia, while data on stunting prevalence were obtained from the Ministry of Health. Additional economic indicators were sourced from the Ministry of Finance.

Figure 1. Research Framework



To analyze the relationship among variables across provinces and over time, this study employs panel data regression analysis, which allows examination of both cross-sectional variation among provinces and time-series dynamics during the study period. Panel data analysis is considered more efficient because it increases the number of

observations and improves estimation accuracy compared to purely cross-sectional or time-series analysis. To determine the most appropriate panel regression model, several model selection tests were conducted. The Chow test was used to compare the Common Effect Model (CEM) with the Fixed Effect Model (FEM). Furthermore, the Hausman test was applied to determine whether the Fixed Effect Model or the Random Effect Model (REM) is more suitable for the dataset. In addition, the Lagrange Multiplier (LM) test was employed to compare the Random Effect Model with the Common Effect Model. These tests ensure that the selected model provides the most consistent and efficient estimation for explaining the relationship between socio-economic determinants, economic growth, and stunting prevalence.

Furthermore, to evaluate the mediating role of economic growth, the analysis examines the direct and indirect effects of socio-economic variables on stunting prevalence using a panel regression framework. This approach enables a more comprehensive understanding of how socio-economic factors influence stunting both directly and indirectly through economic growth. The mediation role of economic growth in the relationship between the independent construct (social assistance, literacy, food security, and unemployment) and the dependent construct (stunting) was evaluated using the Sobel test. The research framework is shown in Figure 1.

This methodology provides a holistic view of the relationships and the total effects of the variables. The analytical procedure adopted in this research is panel data regression, which uses both cross-sectional and time-series data, allowing measurement of the same cross-sectional units at varying points in time. This technique provides information on the cross-sectional and time dimensions of the data.

Regression Equation 1

$$\mathrm{STN}it = \alpha + \beta 1\mathrm{SFA}it + \beta 2\mathrm{LTR}it + \beta 3\mathrm{FS}it + \beta 4\mathrm{UNF}it + \beta 5\mathrm{EG}it + \varepsilon it \quad (1)$$

Regression Equation 2

$$\mathrm{EG}it = \alpha + \beta 1\mathrm{SFA}it + \beta 2\mathrm{LTR}it + \beta 3\mathrm{FS}it + \beta 4\mathrm{UNF}it + \varepsilon it \quad (2)$$

Description:

STN : Stunting
SFA : Social Food Assistance
LTR : Literacy
FS : Food Security
UNF : Unemployment
EG : Economic Growth
ε : Error term
I : Province-level data
t : Period data

The mediation role of economic growth in the relationship between the independent construct (social assistance, literacy, food security, and unemployment) and the dependent construct (stunting) was evaluated using the Sobel test.

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RESULTS AND DISCUSSION

Table 1 presents the results of the model selection tests used to determine the most appropriate estimation model for each equation. The selection process involves the Chow test, Hausman test, and Lagrange Multiplier (LM) test to compare alternative panel data models. Based on these tests, the Fixed Effects Model (FEM) is identified as the most suitable model for both equations, indicating that individual-specific effects play an important role in explaining variations in economic growth and stunting across observations.

Table 1. Model Selection Test Results

Test	H_0	Equation 1	Equation 2
Chow Test	FEM vs CEM	F = 47.2134*** Prob = 0.0000	F = 39.8821*** Prob = 0.0000
Hausman Test	FEM vs REM	χ^2 = 32.5614*** Prob = 0.0000	χ^2 = 28.3197*** Prob = 0.0000
LM Test	REM vs CEM	LM = 86.4523*** Prob = 0.0000	LM = 74.1182*** Prob = 0.0000
Selected Model	-	FEM	FEM

Notes:
*** Significant at α = 1% (p-value < 0.01)
** Significant at α = 5% (p-value < 0.05)
* Significant at α = 10% (p-value < 0.10)

Source: Data Analysis Results (2026)

Based on the data presented in Table 1, the model selection test results are shown for two dependent variables, namely *Economic Growth* and *Stunting*. The results of the Chow and Hausman tests for both dependent variables indicate significance values of 0.0000, which are lower than the 0.01 significance level. This implies that, for the *Economic Growth* variable in Equation 1 and the *Stunting* variable in Equation 2, the Fixed Effects Model (FEM) is more appropriate than the Random Effects Model.

Following the selection of the Fixed Effects Model (FEM) as the most appropriate specification, the analysis proceeds to hypothesis testing to examine the effect of each independent variable on the dependent variable. Table 2 presents the estimation results for Model 1, highlighting the direction and significance of the relationships between social food assistance, literacy, food security, unemployment, economic growth, and stunting.

Table 2. Hypothesis Testing Report Model 1

Variable	Coefficient	t-Statistic	Explanation
C	430.3457	7.518565	
Social Food Assistance	-1.884438	-6.572398	Accepted
Literacy	-0.039117	-1.991975	Accepted
Food Security	-0.213521	-2.957974	Accepted
Unemployment	-2.663792	-6.813352	Rejected
Economic growth	-53.81984	-6.030296	Accepted

Source: Data Analysis Results (2026)

The results show that Social Food Assistance has a significant effect on stunting. This implies that an increase in Social Food Assistance reduces the prevalence rates of stunting. This can be explained through pathways that improve the availability of nutritious food for low-income families. Food aid programs, such as the Social Food Assistance Program, ensure that beneficiary families purchase food items in accordance with their needs and nutritional requirements. Through Social Food Assistance, household purchasing power improves, enabling families to buy a broader range of more nutritious foods, such as fruits, vegetables, and animal-sourced foods. Enhanced intake of nutritious foods improves child nutrition status, which in turn reduces the risk of stunting. These results agree with previous work by Rukiko et al. (2023), which indicates that participation in food aid programs has adverse effects on efforts to reduce stunting. Likewise, Cliffer et al. (2020) examined the effects of social aid programs, including Household conditional cash transfer (CCT), on stunting. They concluded that such programs improve children's nutritional status and reduce the risk of stunting (He et al., 2024).

The research indicates that literacy negatively affects stunting. Specifically, among parents, literacy is often associated with the capacity to comprehend nutrition and appropriate information on childcare practices, health, and other relevant topics. Literacy skills involve the ability to read and write, as well as to retrieve information to improve the family's welfare. Higher literacy levels improve mothers' understanding of nutrition and health practices, thereby promoting children's growth. Maternal literacy is also associated with the ability to retrieve health information, such as the need for exclusive breastfeeding, immunizations, and a balanced diet, which help combat stunting. This finding is consistent with previous studies by Alsubaie (2022), which showed that Literate mothers tend to have children with appropriate Dietary Intake, which in turn lowers the chances of stunting by 30% in rural areas. This is due to mothers having a better understanding of the content and significance of nutrition and health messages. Research shows that Stunting prevalence can be reduced in developing countries where maternal literacy is considered necessary. This is because higher maternal literacy translates into better access to healthcare services and household financial resources to support children's nutrition (Alsubaie, 2022).

The results suggest a significant inverse relationship between food security and child stunting. A household that is firmly food secure can ensure that children have stable access to adequate food and nutrition, which enhances their growth and development. This is consistent with the evidence that food security enhances nutrition and can entirely stave off chronic malnutrition in children. The results above align with Mekonnen (2024), who found that children from low-Food Security households are at higher risk of stunting than their counterparts in food-secure households. Households with adequate food nutrition can then procure healthy foods for their children, which lowers the chances of stunting (Mekonnen, 2024). Adam Smith emphasizes that greater access to resources, enabled by improved distribution and trade, can lead to improvements in the economy and population health (Alderman et al., 2023). The case is also supported by Amartya Sen's Entitlement Theory, which emphasizes the need to enable local communities to build their own

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food systems to increase Food Security (Abbood, 2024). Improved food security affects children's health and cognitive and physical development, thereby enhancing long-term economic productivity (Becker, 2023).

From the findings, stunting is adversely affected by unemployment, but in an inverse relationship. This suggests that the level of stunting does not correlate with unemployment levels within the regions. Consequently, it emerges that there are other underlying reasons for the decline in stunting across all regions. These observations are comparable to the findings of Tekeba et al. (2023), who also observed that Unemployment and poverty rates are closely related to human development indices but have no significant effect on stunting indices. According to the research findings, this study confirms a negative relationship between economic growth and stunting; thus, an increase in economic growth is associated with a reduction in stunting prevalence in Indonesia. This shows that increased economic activity increases the availability and accessibility of food, enabling families to meet the nutritional needs of their young children and thereby reducing stunting. These findings support those of Jumhur (2024), who found that growth in the primary sector is beneficial in the fight against stunting, whereas growth in the secondary sector is detrimental. Likewise, Suryana and Azis (2023) established a direct causal link: higher economic expansion is associated with lower stunting prevalence, although other socioeconomic variables moderate the effect.

This trend indicates that strong economic growth creates opportunities for families to expand their incomes, helping them afford food and their children's nutritional needs. With economic growth, families get opportunities to raise their incomes, leading to increased expenditure on the diet and nutrition of the entire family unit. Moreover, steady economic growth goes hand in hand with the development of infrastructure, healthcare, and educational institutions, which work together to promote children's well-being. Health care and education, once available, help children's families access the nutritional and health information needed to prevent stunting (Panda, 2024).

Table 3. Hypothesis Testing Report Model 2

Variable	Coefficient	t-Statistic	Explanation
C	6,385849	123,8658	
Social Food Assistance	0,014748	5,937009	Accepted
Literacy	0,001515	10,91102	Accepted
Food Security	0,000500	1,742500	Accepted
Unemployment	0,004830	1,274633	Rejected

Source: Data Analysis Results (2026)

Based on the modeling outcomes, the Fixed Effect Model (FEM) was deemed the most suitable, as shown in Table 3. The study's results show that social food assistance has a positive, significant influence on economic development. This is consistent with the work of Panda (2024), who observed that food assistance programs in India enhanced the

purchasing power of people experiencing poverty, thereby increasing their consumption. In addition, programs like these provide direct transfers to the poorest segments of the population, thereby decreasing poverty and economic inequality. Social Food Assistance, in particular, has also been said by Fernandes and Samputra (2022) to influence economic growth (Fernandes & Samputra, 2022). In the same vein, Ceesay et al. (2022) affirmed that Gambia's government reinforced social assistance programs to achieve economic growth in productive sectors of food security, poverty eradication, adaptation and development, education affordability, and quality of governance (Ceesay et al., 2022). According to Richard Musgrave's theories on fiscal policy, the redistribution of funds through social programs has been effective in stimulating the economies of developing countries (Atkinson, 2023).

The study reveals a strong positive relationship between literacy and economic development. This study is consistent with the findings of Hanushek and Woessmann (2020), who reported that a 1% increase in average educational attainment per worker in the country will result in a 1.56% increase in output (Hanushek & Woessmann, 2020). Likewise, Boris et al. (2023) found that literacy levels were positively correlated with economic growth. Educational institutions have placed more focus on tertiary and secondary education, where they train people in employable skills (Boris et al., 2023). The research findings reveal that food security positively impacts Indonesia's economic growth. Ceesay et al. (2022) observe that, as data on population and urban expansion increase, there are limited developments in food production because farmland is becoming smaller. Poor transportation and storage facilities have also led to high post-harvest losses and food distribution problems, limiting the potential of Food Security to contribute to economic growth (Ceesay et al., 2022). There is a conventional perception that even if the lifted Food Security brings about increased food supply, it only sometimes leads to greater agricultural production efficiency or innovations. It is crucial to note that other dimensions, such as government policies, overseas capital injections, and foreign market conditions, also affect economic development.

A study conducted by Hartono et al. (2023) inferred that, within the Indonesian context, the Food Security-economic growth relationship varies in its effect in the short run and, at times, may even be harmful (Akseer et al., 2022). In the same vein, statistics from the Ministry of Finance (2024) showed that agriculture's Gross Value Added accounts for only 13.57% of GDP. However, its growth was 1.46% YoY as of Q3 2023, underscoring the association between agricultural development and economic growth. Timmer (2023) argued that Food Security in Indonesia is actually determined, rather than determined, by pro-poor economic growth and the Green Revolution (Timmer, 2023). There is a need to adopt a more integrated policy approach to avoid the siloed treatment of food security, human capital, infrastructure investment, and other economic sector investments (Fernandes & Samputra, 2022; He et al., 2024).

The conclusions from this research show that Unemployment in Indonesia does not significantly hinder economic growth. Other determinants of economic growth include regional economic profiles, core sectors of the economy, and government policies. Ngubane

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et al. (2023) concluded that, despite turbulent business cycles and high unemployment, poverty declined and the Human Development Index (HDI) continued to increase annually. However, employment levels exerted a noticeable impact on economic growth trends (Ngubane et al., 2023). Hasiru et al. (2024) confirmed the same idea, arguing that there is no meaningful association between economic growth and unemployment, indicating a non-linear relationship (Hasiru et al., 2024). Pratama et al. (2021) did not find any semblance of such a relationship, arguing that economic growth is instead dominated by active sectors such as agriculture, forestry, and fisheries (Palahudin et al., 2024).

The Sobel test assesses whether the ratio of the indirect effect coefficient to its standard error exceeds the critical value for statistical significance. The results show that economic growth plays a significant mediating role in the relationship between socio-economic variables and stunting (see Table 4). Social food assistance, literacy, and food security indirectly reduce stunting through economic growth, suggesting that improvements in these factors foster stronger economic conditions that support child nutrition outcomes. Similarly, unemployment also shows an indirect effect on stunting through economic growth. These findings suggest that economic growth strengthens the impact of socio-economic policies in reducing stunting prevalence.

Table 4. Results of the Sobel Test

Influence	Direct	Indirect	Total	Z-Score	Explanation
Social Food Assistance →	-1,8844	-0,7937	-2,6781	4.4270	Accepted
Literacy →	-0,0391	-0,0815	-0,1206	1.9910	Accepted
Food Security →	-0,2135	-0,0281	-0,2416	2.2657	Accepted
Unemployment →	-2,6638	-0,2599	-2,9237	4.5350	Accepted

Source: Data Analysis Results (2026)

In economic growth, social food assistance is an essential factor in reducing stunting. Welfare, in Amartya Sen's conceptualization of a society's social order, goes beyond the superficial numbers of aggregate economic growth to the people's ability to attain a valued range of being and doing in life. Sen elaborated that stunting is not only a matter of biology but also of resources, and that it is related to the community's capacity to access adequate nutrition and health facilities (Bhtacharya et al., 2016). These results are consistent with Happy (2023), who noted that economic development mediates the relationship between social assistance and stunting. Access to social assistance increases low-income families' purchasing power, giving them a better chance to meet their necessities, including food, healthcare, and education (Ahmed et al., 2022). Research by Ahmed et al. (2022) shows that people with higher levels of education and literacy are more effective at ensuring that children are fed nutritiously. This finding supports the Human Capital Theory, which holds that adult productivity and economic growth improve with education.

As discussed earlier, food security does affect stunting, but economic growth primarily drives it. According to social welfare theory, food security is vulnerable to anti-nutrition

and helps children grow up well. Parents who have access to better food for their children can directly help reduce stunting. Food security improves, with positive results for labor productivity, poverty, and living standards. As previous studies by Akseer et al. (2022) have shown, food insecurity profoundly contributes to stunting.

The research findings on the relationship between unemployment and stunting indicate that unemployment indirectly affects stunting through economic growth. Lower unemployment levels raise families' earnings, enabling parents to provide proper nutrition for their children, thereby directly improving health and reducing stunting. Other studies: Ceesay et al. (2022) support the creation of jobs as a long-term cure for stunting. According to Tekeba et al. (2023), economic employment growth encourages nutrition, which is a relationship that improves the standard of living and combats poverty (Tekeba et al., 2023).

CONCLUSION

The findings of this study indicate that food insecurity is associated with higher stunting prevalence, while social food assistance and literacy play important roles in reducing stunting by improving nutrition awareness, health practices, and parenting knowledge. Unemployment does not directly influence stunting; however, economic growth plays a significant role in reducing stunting by improving household income and access to nutritious food and health services. Furthermore, social food assistance and literacy contribute positively to economic growth, which in turn strengthens efforts to reduce stunting. These results highlight the importance of integrated policies that combine social food assistance programs with nutrition and health education to effectively reduce stunting. In addition, government interventions should prioritize vulnerable households, particularly families with children and pregnant women, while expanding public education through digital platforms and community outreach. Strengthening the synergy between social assistance, education, and economic development is essential to accelerate stunting reduction in Indonesia.

Based on these findings, the government is recommended to integrate social food assistance programs with comprehensive nutrition and health education, particularly targeting vulnerable households such as families with young children and pregnant women. The use of digital platforms and community outreach programs should be expanded to improve public literacy more equitably. Furthermore, the synergy between social assistance policies, literacy improvement, and inclusive economic growth must be strengthened through cross-sectoral coordination among relevant ministries, local governments, and development partners in order to accelerate sustainable stunting reduction across Indonesia

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The Impact of Remittance Inflows on Economic Growth: Evidence from Asian Countries

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ABSTRACT

Research Originality: The originality of this research stems from its extended observation period, the inclusion of detailed macroeconomic control variables, and the analysis of both immediate and sustained effects of remittances on economic growth.

Research Objectives: This study aims to analyze the impact of remittances on economic growth in 22 Asian countries over the period 2004–2023.

Research Methods: This study employs a panel data approach using the Generalized Method of Moments (GMM) to address econometric issues such as endogeneity and unobserved heterogeneity, while incorporating variables including foreign direct investment, inflation, population growth, education, household consumption, government expenditure, and exports.

Empirical Results: The findings indicate that remittances have a positive effect on economic growth in both the short- and long-run. However, the short-run impact is not always statistically significant. Exports and inflation show positive effects, whereas foreign direct investment and education show negative effects in some specifications.

Implications: These results suggest that remittances play an important role as a complementary source of development financing in Asian economies, and policymakers should encourage their productive use to strengthen sustainable economic growth.

Keywords:
international migration; external financing; macroeconomic stability; human capital development; investment activity

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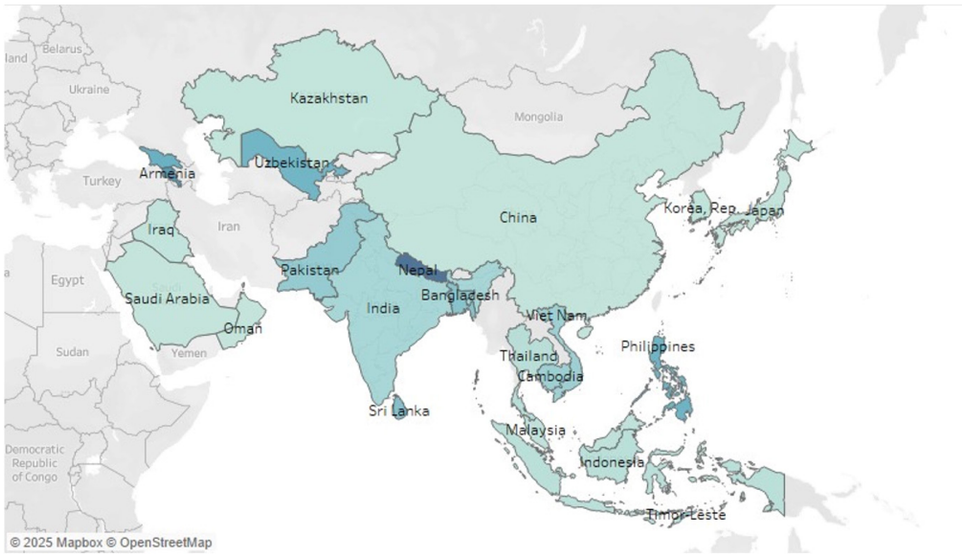
INTRODUCTION

Remittances, defined as financial transfers sent by migrant workers to their families in their home countries, have become an important source of external finance for many developing economies. In recent decades, remittance inflows in several countries have even exceeded foreign aid and foreign direct investment. This trend is particularly evident in Asia, especially in South and Southeast Asia, including India, the Philippines, Nepal, Pakistan, and Indonesia. Asia is currently the largest recipient of remittances globally. For example, India received more than USD 87 billion in remittances in 2023, making it the world's largest recipient. Similarly, the Philippines and Bangladesh rely heavily on remittances to support household welfare and maintain economic stability. In extreme cases, remittances account for a very large share of national income; for instance, in Tajikistan, remittance inflows exceeded 49% of GDP. Meanwhile, emerging market economies such as Indonesia, Pakistan, and Vietnam have also experienced significant increases in remittance inflows. Indonesia alone received more than USD 12 billion in remittances in 2022. However, in many cases, remittances are primarily used for household consumption rather than productive investment (Mills, 2023).

Figure 1. Distribution of Remittances in Asian Countries, 2025



Source: author's calculation

Remittances have become a key source of income for many developing countries. The 2017 United Nations Migration Report highlights that most migrants come from Asia and Africa. For many developing economies, remittances are a vital source of external financing, often surpassing other income sources (Barkat et al., 2024). South Asian and Southeast Asian countries are among the top recipients of remittances worldwide. According to World Bank research, these remittances play a crucial role in supporting household welfare and economic stability in developing nations. Barnadi et al. (2025) emphasize the importance of remittances for the economy, while Ojeyinka & Ibukun (2024) show that they serve as

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a key mechanism to reduce income inequality, enhance living standards, combat poverty, and promote economic growth in Central Asia. In 2023, Nepal received around USD 8.5 billion in remittances, accounting for over 30% of its gross domestic product (GDP) (World Bank, 2025). In Nepal, most remittances are used for household consumption, education, and healthcare.

Data from Bank Indonesia and the World Bank show a steady rise in remittance inflows to Indonesia. In 2022, the country received about USD 12.3 billion in remittances, up from USD 11.3 billion in 2021 (World Bank, 2025). Most of these remittances are used for daily expenses, education, and healthcare. They account for roughly 1–2% of Indonesia's GDP, highlighting their importance in boosting household purchasing power and enhancing living standards (Cahyanti & Sugiharti, 2022). Empirical research indicates that remittances are generally linked to economic growth in many developing nations. A study by Huay et al. (2019) examining several developing countries, including India, Indonesia, the Philippines, Nigeria, and Kenya, shows that remittances significantly boost economic growth, especially where dependence on remittance inflows is high. Similar results are found by Mangkornpunt (2021) among ASEAN countries, highlighting that remittances promote growth, with the Philippines experiencing the largest effect and notable impacts in Indonesia, Thailand, and Vietnam.

Research from Latin America also supports this, suggesting that remittances stimulate economic growth by boosting household spending and increasing domestic investment (Ehberger, 2026). Findings from Sub-Saharan Africa also align with this pattern. Dalessa et al. (2024) demonstrate that remittances positively influence growth in various African nations, particularly those heavily reliant on inflows. Similar insights are evident in studies of South and Southeast Asia, which show that remittances can drive economic development by increasing consumption, investment, and macroeconomic stability (Rahman et al., 2019; Azizi et al., 2023). Overall, the literature suggests that remittances are a vital source of development funding for emerging economies.

Most prior research focuses on specific countries or regions, yielding mixed conclusions about whether remittances reliably boost economic growth. For instance, Okara et al. (2010) demonstrate that remittance inflows significantly increase per capita GDP growth in African nations. Similarly, Meyer and Shera (2017) find that remittances positively influence economic growth in Southeast Balkan countries. Additionally, Oladipo (2020) states that workers' remittances positively affect Nigeria's economic growth in both the short and long term, although the effect's elasticity is relatively modest. However, some studies present different findings. Pradhan (2016), analyzing BRICS countries, reports that remittances significantly hinder economic growth in Brazil, Russia, and India, whereas they have a positive impact in China.

Additionally, Islam (2022) suggests that remittances could heighten domestic inflationary pressures. Moreover, Hassan et al. (2017) observe that remittance inflows generally increase with higher levels of education among the population, but may decrease when lower-income groups attain higher levels of education. Matuzeviciute and Butkus (2016) conclude that remittances alone are insufficient to ensure long-term economic development or to address

structural issues such as political instability. Despite the growing literature on remittances and economic growth, previous empirical studies still yield inconsistent findings across countries and regions. Several studies report that remittances positively contribute to economic growth by increasing household consumption and investment and reducing poverty. In contrast, others find insignificant or even negative effects due to inflationary pressures, exchange rate appreciation, and inefficient allocation of remittance funds.

Moreover, most previous studies focus on single-country cases or specific regions, such as Africa, Latin America, or ASEAN, resulting in limited comprehensive evidence for Asian economies as a whole. In addition, a significant portion of the extant literature continues to rely on static estimation techniques, such as Ordinary Least Squares (OLS) and Fixed- or Random-Effects models. These methods, however, are often ill-equipped to mitigate endogeneity biases and the autoregressive nature of economic growth. To address these econometric challenges, this study employs the Generalized Method of Moments (GMM), thereby filling a critical gap in empirical research on dynamic panel estimation and providing broader Asian coverage. Unlike previous studies, this approach provides a unified empirical framework that simultaneously accounts for the dynamic interplay among remittances and key macroeconomic covariates, including FDI, inflation, and human capital.

The literature indicates that the influence of remittances on economic growth varies across countries. Several studies emphasize that economic and institutional contexts shape the effectiveness of remittances. Additionally, remittances tend to have a stronger impact in countries with more advanced financial sectors, as well-functioning financial systems help direct remittances into productive investments and capital accumulation. This is supported by a systematic review showing that remittance effectiveness depends heavily on the quality of the financial system and human capital (Sholehah & Samputra, 2025). To address this gap, our study examines how remittances affect economic growth in 22 Asian countries from 2004 to 2023, using the Generalized Method of Moments for dynamic panel analysis.

The key contributions of this study are threefold. First, it offers comprehensive empirical evidence from Asian economies, drawing on a larger dataset than prior research, which often focused on individual countries or regions. Second, it employs a dynamic panel approach to mitigate endogeneity issues and capture both short- and long-term impacts. Third, it includes a broad set of macroeconomic controls to understand better how remittances influence growth. The main goal is to analyze the short- and long-term effects of remittances on economic growth in these countries from 2004 to 2023, while accounting for factors such as foreign direct investment, inflation, education, household consumption, government spending, and exports. This research aims to contribute fresh insights to the literature on remittances and growth, particularly in the Asian context, using a dynamic panel estimation method.

METHODS

This study investigates how remittances influence economic growth in Asian countries. It analyzes data from 22 Asian nations from 2004 to 2023, using panel data

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to capture both cross-country differences and changes over time. The countries studied include Armenia, Bangladesh, Cambodia, Georgia, Japan, Kazakhstan, Nepal, Oman, Timor-Leste, Uzbekistan, Vietnam, Malaysia, India, Iraq, the Philippines, Saudi Arabia, Pakistan, Indonesia, Thailand, Sri Lanka, South Korea, and China. The chosen data span from 2004 to 2023 for several reasons. First, data from 2004 onward are more reliable and consistent across these countries, especially for key variables such as remittances, education, and household consumption, and are sourced from the World Development Indicators database, since earlier periods have many missing observations. Second, this timeframe captures significant structural changes in global and regional economies, including rapid growth in international migration and remittance flows, as well as key events like the 2008 global financial crisis and the COVID-19 pandemic, which are pertinent to understanding remittances' impact on growth. Third, this period offers sufficient variation across countries and over time to support dynamic panel analysis, allowing examination of both short- and long-term macroeconomic effects of remittance inflows while addressing potential econometric issues such as endogeneity and unobserved heterogeneity. Overall, the 2004–2023 timeframe enables a balanced and thorough empirical investigation.

This study focuses on economic growth as the main dependent variable, measured by the GDP growth rate. The primary independent variable analyzed is remittance inflows. Additionally, several control variables are incorporated to reflect broader macroeconomic factors, including foreign direct investment (FDI), inflation, the productive-age population, education levels, household consumption expenditure, government spending, and exports.

To examine the relationship between remittances and economic growth, this study employs the System GMM estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998). This approach is particularly advantageous for dynamic panel data because it effectively mitigates pervasive econometric issues, including endogeneity, autocorrelation, and unobserved cross-country heterogeneity. By incorporating lagged dependent variables, the GMM framework accurately captures the persistence of economic growth over time. Furthermore, the System GMM variant improves estimation efficiency and circumvents weak-instrument problems by simultaneously estimating equations in both first differences and levels.

$$LnGDPPer_{it} = \alpha + \beta_1 LnGDPPer_{it-1} + \beta_2 REM_{it} + \beta_3 FDI_{it} + \beta_4 INF_{it} + \beta_5 POP_{it} + \beta_6 EDU_{it} + \beta_7 HFC_{it} + \beta_8 GEX_{it} + \beta_9 EXP_{it} + \varepsilon_{it}$$

The variables used in this study are defined as follows. GDPPer represents gross domestic product per capita, an indicator of economic growth. LnGDPPer_{it−1} denotes the lagged natural logarithm of GDP per capita, included in the model to capture the dynamic effect of past economic performance on current growth. REM denotes workers' remittance inflows received by a country. FDI represents foreign direct investment inflows, while INF indicates the inflation rate. POP refers to the productive-age population, which represents the potential labor force contributing to economic activity. EDU represents the percentage of the population that has completed primary education, serving as a proxy for human capital. HFC refers to household final consumption expenditure, GEX denotes

government final expenditure, and EXP represents exports. These variables are included to capture key macroeconomic factors that may influence economic growth (see Table 1).

Table 1. Operational Variables

Variables	Definition	Data Source	Measurements	References
Gross Domestic Product	The total value of goods and services produced within an economy, measured at constant 2015 US dollars.	World Development Indicators (World Bank)	GDP (constant 2015 US$)	Adow, 2025
Remittance	Personal transfers received from migrant workers abroad, measured in current US dollars.	World Development Indicators (World Bank)	Personal remittances, received (current US$)	Adow, 2025
Foreign Direct Investment	Net inflows of investment from foreign entities into the domestic economy, measured in current US dollars.	International Monetary Fund, World Bank	Foreign direct investment, net inflows (current US$)	Adow, 2025
Inflation	The annual percentage change in consumer prices, reflecting the general price level.	International Monetary Fund, International Financial Statistics	Inflation, consumer prices (annual %)	Adow, 2025
Population	Total population aged 15–64, representing the working-age population.	World Development Indicators (WDI)	Population ages 15–64, total	Adow, 2025
Education	The percentage of the population aged 25 and above who have completed at least primary education.	UNESCO Institute for Statistics(UIS), World Development Indicators (WDI)	Educational attainment, at least completed primary, population 25+ years (%)	Khan et al., 2025
Household Final consumption expenditure	Total household spending on goods and services, measured at constant 2015 US dollars.	World Development Indicators (WDI)	Household final consumption expenditure (constant 2015 US$)	Kajtazi & Fetai, 2022
Government final consumption expenditure	Total government spending on goods and services, measured at constant 2015 US dollars.	World Development Indicators (WDI)	General government final consumption expenditure (constant 2015 US$)	Kajtazi & Fetai, 2022
Export	The total value of goods and services exported, measured in current US dollars.	World Development Indicators (WDI)	Exports of goods and services (current US$)	Kajtazi & Fetai, 2022

RESULTS AND DISCUSSION

The empirical findings show that remittances positively influence economic growth in Asian countries both in the short and long term. The System Generalized Method of Moments (Sys-GMM) results also indicate that exports, inflation, and population growth support economic growth, whereas foreign direct investment and education may have negative impacts in some models. Overall, these results highlight the significant role of

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remittances as a supplementary form of external funding and domestic economic aid in Asian economies. Table 2 presents descriptive statistics summarizing the characteristics of the data used in this study, including the mean, standard deviation, minimum, and maximum values. The dataset consists of panel data covering 22 Asian countries, with a total of 440 observations, drawn from cross-country and time-series data. The variables analyzed include economic growth (LnGDPP), remittances (REM), foreign direct investment (FDI), inflation (INF), population growth (POP), education (EDU), household consumption (HFC), government expenditure (GEX), and exports (EXP).

Table 2. Descriptive Statistic

Variable	Obs	Mean	Std. Dev.	Min	Max
LnGDPP	440	1.505	.914	-9.073	3.978
REM	440	5.186	6.838	.003	62.452
FDI	440	2.584	3.558	-30.26	18.599
INF	440	5.198	4.8	-2.093	49.721
POP	440	1.24	1.456	-2.8	14.225
EDU	440	3.461	1.68	0	12.902
HFC	440	59.905	15.522	26.026	97.425
GEX	440	15.518	13.719	4.809	115.924
EXP	440	35.97	21.808	2.409	115.373

Based on Table 2, the variable LnGDPP has a mean value of 1.505 with a standard deviation of 0.914. The minimum and maximum values are –9.073 and 3.978, respectively, indicating substantial variation in economic growth across countries and over the observation period. This variation reflects differences in economic structures and levels of development among the countries included in the study.

Table 3. Multicolinearity Test

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) REM	1.000							
(2) FDI	0.039	1.000						
(3) INF	0.258	0.128	1.000					
(4) POP	-0.219	-0.125	0.013	1.000				
(5) EDU	0.016	0.016	0.021	0.116	1.000			
(6) HFC	0.660	0.163	0.325	-0.318	-0.151	1.000		
(7) GEX	-0.080	-0.122	-0.049	0.173	0.616	-0.063	1.000	
(8) EXP	-0.353	0.279	-0.223	0.179	0.018	-0.416	-0.184	1.000

The REM (remittances) variable has a mean of 5.186 and a relatively high standard deviation of 6.838. The minimum remittance value is 0.003, while the maximum is 62.452. These figures suggest that remittances contribute considerably across countries. In some countries, remittances are a major source of external income, while in others

they play a relatively minor role. Based on Table 3, the correlation results indicate that most of the correlation coefficients among the variables are relatively low to moderate. There are no correlation values exceeding 0.80, suggesting no strong correlation among the independent variables. Therefore, the research model does not exhibit multicollinearity.

Table 4. Sys GMM

LnGDPP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]
L.LnGDPP	.064	.186	0.34	.731	-.3	.428
REM	.033*	.017	1.92	.055	-.001	.066
FDI	-.084***	.022	-3.86	0	-.127	-.041
INF	.021**	.009	2.26	.024	.003	.04
POP	.058**	.025	2.27	.023	.008	.107
EDU	-.161***	.054	-2.97	.003	-.267	-.055
HFC	.024*	.014	1.72	.086	-.003	.052
GEX	.008	.007	1.23	.22	-.005	.021
EXP	.017**	.007	2.29	.022	.002	.031
Constant	-.319	.98	-0.33	.745	-2.24	1.602
Mean dependent var		1.489	SD dependent var			0.914
Number of obs		418	Chi-square			258.860

Note: *** p<.01, ** p<.05, * p<.1

The simultaneous effect is indicated by a Wald Chi-square value of 258.860 with a p-value of less than 0.0001, which is smaller than the significance level of 0.05. Therefore, H1 is accepted, indicating that the variables simultaneously have a significant effect on the dependent variable. Based on the estimation results in Table 4, several variables have significant partial effects on economic growth, measured by LnGDPP: foreign direct investment (FDI), inflation (INF), population growth (POP), education (EDU), and exports (EXP). The lagged variable $LnGDPP_{t-1}$ has a positive coefficient of 0.064, indicating persistence in economic growth: growth in the previous period tends to increase growth in the current period. Remittances (REM) have a positive coefficient of 0.033, suggesting that higher remittance inflows contribute to economic growth by increasing household purchasing power and stimulating domestic economic activity.

However, foreign direct investment (FDI) has a negative coefficient of –0.084, indicating that higher FDI inflows are associated with lower short-run economic growth. Inflation (INF) has a positive coefficient of 0.021, implying that moderate inflation may still support economic growth by boosting aggregate demand. Population growth (POP) also has a positive coefficient of 0.058, suggesting that a larger population can expand the domestic market and labor supply. Meanwhile, education (EDU) has a coefficient of –0.161, indicating that improvements in education do not immediately translate into short-term economic growth due to the time lag in the development of human capital. Household consumption (HFC) shows a positive coefficient of 0.024, reflecting the important role of domestic consumption in driving economic growth. Government

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expenditure (GEX) has a positive coefficient of 0.008, indicating a relatively small but positive contribution to economic growth. Finally, exports (EXP) have a positive coefficient of 0.017, suggesting that higher export performance contributes to economic growth by increasing national income and strengthening integration with global markets.

Table 5. Long-Run Sys GMM

Y	Coefficient	Std.err	z	P>z	[Lower 95% CI]	[Upper 95% CI]
REM	0.035	0.018	1.900	0.058	-0.001	0.071
FDI	-0.090	0.012	-7.390	0.000	-0.114	-0.066
INF	0.023	0.009	2.510	0.012	0.005	0.041
POP	0.062	0.030	2.060	0.040	0.003	0.120
EDU	-0.172	0.072	-2.400	0.016	-0.312	-0.031
HFC	0.026	0.017	1.520	0.127	-0.007	0.059
GEX	0.009	0.006	1.420	0.157	-0.003	0.021
EXP	0.018	0.006	2.780	0.005	0.005	0.031

Based on the estimation results presented in Table 5, five variables show a significant long-run partial effect on economic growth measured by LnGDPP at a significance level of $\alpha < 0.05$, namely foreign direct investment (FDI), inflation (INF), population growth (POP), education (EDU), and exports (EXP). The long-term estimation results show that a one-unit increase in remittances (REM) is associated with a 0.035 increase in LnGDP, indicating that remittances positively and sustainably support economic growth. This aligns with previous research emphasizing the role of remittance inflows in boosting household consumption, encouraging investment, and enhancing human capital development (Ltaif et al., 2024). In contrast, foreign direct investment (FDI) has a negative coefficient of –0.090, indicating it has not yet made an optimal long-term contribution to economic growth. This may be due to weak integration between foreign-invested firms and local industries and significant profit repatriation, as noted by Fazaaloh (2024). Similarly, Ullah (2023) argued that the effectiveness of FDI in fostering economic growth depends heavily on sectoral allocation and regulatory quality in developing countries. Findings from Indonesia by Millia et al. (2023) suggest that the growth benefits of FDI are limited when domestic sectors cannot absorb technological transfer and productivity spillovers. Additionally, Osarumwense and Igor (2023) found that poor institutional quality and limited domestic capacity can diminish the long-term impact of FDI, especially in lower-income nations. Recent studies on South Asian economies also indicate that FDI alone is insufficient to ensure sustainable growth without additional support from domestic investment and human capital development.

Inflation (INF) shows a positive coefficient of 0.023, suggesting that moderate inflation may still stimulate economic activity and support long-run economic growth. This finding aligns with recent studies indicating that low, controlled inflation can encourage production, investment, and aggregate demand without causing substantial macroeconomic instability. For instance, evidence from Indonesia shows that inflation below a threshold may

positively influence economic growth, while excessive inflation tends to hinder performance (Ramadhaniyati et al., 2023). Similarly, Pappas & Boukas (2025) found no strong evidence that moderate inflation negatively affects economic growth in European Union economies. Cross-country evidence by He (2023) further revealed an inverted-U relationship between inflation and growth, implying that moderate inflation levels may still be growth-enhancing before exceeding a harmful threshold. In addition, Azam & Khan (2022) argued that inflation becomes detrimental only when it exceeds a specific threshold, whereas low inflation remains compatible with sustainable growth. Empirical findings from Indonesia also showed that inflation had a positive and significant impact on economic growth during the post-pandemic recovery period (Adelia & Hermana, 2026).

Population growth (POP) has a positive coefficient of 0.062, suggesting that an expanding population can boost domestic demand, increase the labor force, and enhance production capacity over time. This aligns with endogenous growth theory, which highlights the importance of human capital and labor force expansion for sustainable economic development. Recent empirical research supports this, showing that population growth can positively impact economic performance when coupled with improvements in human capital, labor productivity, and institutional capacity. For example, studies from Nigeria demonstrate that population growth, combined with human capital development, contributes to long-term economic growth through higher labor force participation and productivity (Adebayo et al., 2024). Similarly, research in Ethiopia indicates that population increases can stimulate economic growth by expanding the labor supply and domestic production (Alemu & Zegeye, 2024). A study from Indonesia emphasizes that investments in human capital and labor quality significantly support economic growth within the endogenous growth framework, where productive population growth is a key driver of long-term output (Suparman & Muzakir, 2023). Evidence from ASEAN countries also shows that a larger working-age population boosts economic growth through increased labor participation, investment, and productivity gains (Trong et al., 2024). Additionally, recent analyses of endogenous growth models highlight that sustained economic development remains strongly linked to labor quality, innovation, and human capital accumulation, even amid demographic changes (Strulik, 2024).

The education variable (EDU) shows a negative coefficient of –0.172, indicating that increases in educational attainment do not lead to immediate economic growth. This likely reflects the time lag in human capital development, in which the benefits of education take time to manifest as higher productivity, better labor market integration, and more specialized skills. In line with Hanushek & Woessmann (2010), the growth effects of education depend not just on years of schooling but also on the quality of cognitive skills, institutional quality, and the labor market's ability to absorb new skills. In many developing countries, the short-term impact of education is often limited by structural issues such as skill mismatches, educated unemployment, and a lack of productive employment opportunities (Semenova et al., 2023). Additionally, the long-term impact of education on economic growth is greatly enhanced when combined with technological innovation and improvements in human capital quality (Goczek et al., 2021).

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Household final consumption (HFC) shows a positive coefficient of 0.026, highlighting its role as a key driver of economic growth through increased aggregate demand. This result supports recent empirical studies indicating that strong household spending boosts the economy by spurring production, investment, and employment—especially in emerging markets reliant on consumption (Kim & Park, 2024). Additionally, post-pandemic research underscores that resilient household consumption enhances economic stability and speeds up recovery by generating multiplier effects on domestic industries and stabilizing overall demand (Chen et al., 2024).

Government expenditure (GEX) shows a modest positive coefficient of 0.009, suggesting that public spending positively affects long-term economic growth. This aligns with recent empirical research indicating that productive government expenditure—especially in areas like infrastructure, education, and public services—can boost economic performance by encouraging investment, increasing productivity, and supporting overall demand (Nguyen et al., 2023). Finally, exports (EXP) have a positive coefficient of 0.018, indicating that improved export performance encourages economic growth by boosting national income, foreign exchange earnings, and integration into global markets. This finding supports the export-led growth hypothesis, which posits that increased exports enhance productivity and economic efficiency, particularly in developing and emerging economies (Rahman & Kashem, 2022).

CONCLUSIONS

This study examines the impact of remittances on economic growth in 22 Asian countries from 2004 to 2023, using the System GMM (Sys-GMM) estimator. The findings indicate that remittances have a positive effect on economic growth in both the short and long run, though the short-run effect is not always statistically significant. In the long run, remittances contribute positively and consistently to economic growth by supporting household consumption, investment, and overall economic stability. In addition, exports, inflation, and population growth contribute positively to economic growth, while foreign direct investment and education exhibit negative effects in certain model specifications. This study contributes to the literature by providing updated empirical evidence from Asian economies using a dynamic panel estimation framework and a comprehensive set of macroeconomic control variables. The findings confirm that remittances play an important role as a complementary source of external financing for developing economies.

Based on these findings, several policy recommendations can be proposed. Governments in Asian countries should encourage the productive use of remittances by strengthening financial inclusion, expanding access to formal banking services for migrant workers and their families, and promoting investment-oriented remittance programs. Policymakers should also support the development of small and medium-sized enterprises (SMEs) and productive sectors capable of absorbing remittance-based investments. In addition, improving the quality of education, labor market capacity, and digital financial infrastructure is important for maximizing the long-term economic benefits of remittance inflows. While this study offers valuable insights, its scope is constrained by the available data and the countries covered.

Future research should consider including variables such as institutional quality, financial development, governance, and technological innovation to deepen the understanding of how remittances influence economic growth.

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From Depositors' Confidence to Credit Stability: The Role of Deposit Insurance

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ABSTRACT

Research Originality: This study assesses the impact of deposit insurance on depositors' confidence and credit stability, incorporating gap dynamics, crisis phases (pre-, during, and post-COVID-19), and bank ownership heterogeneity.

Research Objectives: This study examines the effect of deposit insurance on depositor confidence and its implications for deposit stability, and the impact of deposit stability on banks' confidence in credit allocation.

Research Methods: Three datasets- monthly macroeconomic time-series data (January 2002–May 2023) and two panel datasets covering October 2005–May 2023 and March 2012–May 2023 are estimated using PLS and OLS.

Empirical Results: Deposit insurance effectively stabilizes depositor confidence, especially at private institutions. Throughout the COVID-19 pandemic, deposit insurance became increasingly critical in maintaining market sentiment. This stability in depositor confidence drives deposit accumulation, which in turn catalyzes credit supply both during and after crises. Additionally, findings suggest that depositor behavior and bank stability are sensitive to domestic and global economic fluctuations.

Implications: The study recommends strengthening deposit insurance institutions and improving coordination among institutions to stabilize deposits, credit, and the financial system.

Keywords:
deposit insurance; bank; deposit; credit; confidence

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INTRODUCTION

The role of credit in the economy provides the primary motivation for this study. Credit availability enables households, small and medium-sized enterprises, and large corporations to finance productive investments. The investment fosters job creation, innovation, and the development of new economic sectors. Credit enables expenditures on short-term needs and helps reduce the risk of future economic instability by mitigating financial constraints and cash-flow volatility. The Studies by Thierry et al. (2016), Ananzeh (2016), Gambetti and Musso (2017), Ahn and Sarmiento (2019), Ho and Saadaoui (2022), Bottero et al. (2020), Akinci and Queralto (2022), Guerrieri et al. (2022), Baqaee and Farhi (2022), and Kiselev et al. (2025) find that credit, through its impact on investment, consumption smoothing, and the transmission of economic shocks, contributes to macroeconomic stability and growth.

Credit exhibits pro-cyclical behavior: during economic recessions, when significant investment is needed for economic recovery, credit availability typically declines. Conversely, during periods of economic expansion, when output exceeds potential, credit growth increases. In situations of economic overheating, excessive credit growth is often harmful and can lead to the onset of a crisis (Wijaya et al., 2025; Ivashina et al., 2024; Albanesi, 2022; Bleck & Liu, 2018; Krishnamurthy & Muir, 2017; Davis et al., 2016; Bernstein et al., 2016). The interaction between economic cycles and credit is a key focus for monetary authorities (Kiyotaki & Moore, 2019; Deng et al., 2022; Yuan & Liu, 2026). Authorities use monetary and macroprudential policies to maintain financial system stability and address credit procyclicality (Fahr & Fell, 2017; Chadwick, 2018; Matysek-Jędrych, 2018). Studies by Aiyar et al. (2016), Chen et al. (2016), Triandhari et al. (2017), and Robstad (2018) found a mixed impact of these policies on credit dynamics.

The experience of the banking crisis demonstrates that credit-only policies are insufficient to maintain banking stability. Policies governing bank funding sources are also crucial, given the risks associated with providing credit. Unlike banks, which cannot demand immediate repayment from borrowers, depositors can withdraw their cash at any time. Credit terms generally exceed the duration of deposits. Consequently, banks require assistance to fulfill their responsibilities to depositors in the event of massive withdrawals, which can lead to banking paralysis. Banking paralysis can quickly trigger a severe economic crisis. Various studies have demonstrated a link between economic crises and financial stability, including in conventional and Islamic banking (Alqahtani & Mayes, 2018; Batuo et al., 2018; Law & Ridhwan, 2022; Kurtoglu & Durusu-Ciftci, 2024).

A significant bank run transpired in Indonesia in 1997-1998 following the revocation of business licenses for 16 national private banks (Simorangkir, 2011, 2012). The revocation of this permit led to a systematic withdrawal of funds from the banking sector. To prevent systemic paralysis in the banking system, the government established blanket guarantees for current, time, and savings deposits, providing comprehensive protection. Despite its high cost, this policy successfully reinstated depositors' confidence and protected the Indonesian banking sector. In 2004, a deposit insurance agency was established to offer limited guarantees for public deposits, informed by this experience.

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The experience of Indonesian banking shows that credit control through monetary and macroprudential policies is insufficient to maintain credit stability. Efforts to maintain bank liquidity by protecting depositor confidence will reduce the risk of massive withdrawals (bank runs). Deposit insurance is crucial for banks because it ensures depositors' confidence that their funds are secure. Depositors can be assured that their funds are safe and guaranteed to be returned, even if the bank goes bankrupt. This maintains overall financial stability by increasing depositor confidence and reducing systemic risk. Several studies have found a relationship between bank runs, deposit insurance, and liquidity models (see Diamond & Dybvig, 1984; Wardhana & Sufitri, 2019).

However, Calomiris and Jaremski (2016), Anginer and Demirgüç-Kunt (2018), Ngalawa et al. (2016), Egbuna et al. (2018), Kusairi et al. (2018), and Sahadewo (2018) indicate that the deposit insurance system may face moral hazard challenges. Effective management of deposit insurance requires a financial safety net guarantee institution. Anginer and Demirgüç-Kunt (2018) emphasize the impact of deposit insurance on moral hazard behavior. Additionally, the research conducted by Gropp and Vesala (2001) demonstrates that deposit insurance reduces banks' risk-taking behavior (see also Wilcox & Yasuda, 2019; Jeroh, 2020). Casu et al. (2019) identify five key characteristics of a Financial Safety Net: first, the presence of effective regulations and supervision; second, a deposit guarantee scheme; third, the role of a lender of last resort; fourth, the implementation of bank insolvency and resolution mechanisms to maintain customer trust; and fifth, the necessity for coordination among the components of the Financial Safety Net.

The previous studies by Calomiris and Jaremski (2016), Anginer and Demirgüç-Kunt (2018), Ngalawa et al. (2016), Egbuna et al. (2018), Kusairi et al. (2018), and Sahadewo et al. (2018) examine the potential for moral hazard arising from the comprehensive guarantee of full deposits. To address moral hazard, the Deposit Insurance Corporation in Indonesia (Lembaga Penjamin Simpanan-LPS), established in 2005, limits its guarantee to specific deposits. Additionally, to mitigate moral hazard, LPS establishes a maximum guaranteed interest rate that banks may offer customers. If a bank offers an interest rate that exceeds the guaranteed rate, the deposit is not protected by LPS (LPS: 2023).

This study aims to examine the impact of deposit insurance on depositor confidence, which is essential for sustaining the stability of bank deposits, and on banks' confidence, which affects credit stability. This study examines the relationship between bank deposit stability and bank confidence, and how this relationship affects the volume of credit extended by banks. The analysis encompasses macroeconomic conditions, implemented policies, crises, and bank ownership. The deposit and credit gaps serve as indicators of depositors' and banks' confidence levels.

This study introduces four novelties. First, it incorporates gap variables, which describe deviations (shocks) rather than trends. The trends are considered equilibrium values and anticipated by economic agents. Second, we integrate macroeconomic variables into a model of deposits and credit. The macroeconomic variables are based on the general equilibrium. Third, the model incorporates the three phases of the crisis (pre-COVID-19,

during, and post-COVID-19). This inclusion is crucial, as the role of deposit insurance becomes more pronounced during crises. This study uses three models: a macroeconomic model, a savings model, and a credit model. Finally, the model distinguishes between government-owned banks and non-government banks. We assume that public trust in deposit placement is higher at government-owned banks than at non-government banks.

We employ a three-step estimation and three models to assess the influence of deposit insurance on credit. The initial model is a macroeconomic general equilibrium model. The model's estimates are used to derive the anticipated values of macroeconomic variables for the subsequent two models: the savings model and the credit model. Additionally, within the savings model, we examine the effects of deposit insurance on deposits, while in the credit model, we analyze the impact of deposits and deposit expectations on credit. We incorporate the deposit and credit gaps into the equation.

METHODS

This study uses three monthly data sets. First, time-series data from January 2002 to May 2023 for estimating the macroeconomic Model. Second, panel data from September 2005 to May 2023 for estimation of the Deposits Model. Third, panel data from March 2012 to May 2023 for estimating the Credit Model. In the first group, we use monthly data on year-on-year inflation, policy interest rates, deposit interest rates, and the Rupiah exchange rate against the USD. We also use quarterly Gross Domestic Product (GDP) data with 2010 as the base year. Nominal GDP is converted into real GDP using the GDP deflator, so it reflects constant 2010 prices. The real GDP data is then adjusted for seasonal effects using the X-12 Census method. After that, the quarterly GDP data is interpolated to obtain monthly data.

Furthermore, central government expenditure is adjusted using the GDP deflator to obtain expenditure at constant 2010 prices. Data for the period from 2020 to 2023 are provided monthly. However, since the other period is quarterly, this study employs interpolation techniques to generate monthly data for other periods. This study also incorporates measures of output gap ($\hat{y}$), gap in central government spending ($\hat{g}$), gap in deposit interest rates ($\widehat{id}$), year-on-year gap of inflation ($\hat{\pi}$), depreciation of the Rupiah against the USD ($\dot{er}$), deposit gap ($\widehat{dpk}$), and credit gap ($\widehat{cr_t}$). Gaps can be calculated as follows (see Utama et al., 2022):

$$\hat{x} = \frac{x - x^*}{x^*} \quad (1)$$

where x is the actual value of *y, g, id, π, dpk* or cr and x^* is the equilibrium value of the variables. The x^* value is obtained using the Hodrick–Prescott filter, or HP Filter.

The variables Deposit and credit represent the aggregate of Third Party Funds and total credit across state-owned, local government-owned, private, foreign, and joint-venture banks. Deposit expectations are derived from estimating the deposits equation. The guaranteed interest is the maximum interest rate set by the LPS that banks can offer savers. Economic conditions in the model are represented by the output gap and

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inflation expectations, which are estimated from macroeconomic equations. Several dummy variables are used in estimating the deposits and credit model, including those for the COVID-19 crisis, bank ownership, and bank type. The descriptions of the variables are shown in Table 1.

Table 1. Description of Variables

Macroeconomic Model		
Name of Variable	**Sign**	**Explanation**
GDP	y	Prices constant 2010. Seasonally adjusted. Quarterly data are interpolated into monthly data. Source BPS.
Fiscal policy	g	Central government spending. The 2002-2019 period uses quarterly data. The data is interpolated into monthly data. 2020-2003 data is monthly data. Central government expenditure values are converted to constant 2010 prices. Source MoF.
Deposit interest rate	i^d	3-month term deposit interest rates for commercial banks. Source BI
Monetary policy	i	Policy interest rate. BI Source
Year-on-year inflation (*yoy*)	π	Calculated using CPI
Depreciation Rp/USD	$\dot{e}r$	Monthly depreciation Rp/USD. BI Source
Dummy for negative output gap	$D\hat{y}N_{t-3}$	$D\hat{y}N_{t-3} = 1$, Negative output gap $D\hat{y}N_{t-3} = 0$, other
Deposit and credit models		
Variable	**Sign**	**Explanation**
Deposit (*Third Party Funds*)	dpk	Deposit includes time, savings, and demand deposits of government and private banks.
Deposit insurance policy	i_t^p	Deposit insurance interest rates.
COVID-19	dcv	dcv =0, Before 2020; dcv =1, January 2020 to May 2023
Expected economic condition	$E\hat{y}$	Fitted value of market equilibrium equation.
Expected inflation	$E\hat{\pi}$	Fitted value of Phillips Curve.
Dummy of bank: government (central and local government)	dg	dg =1, owned by government, dg =0 others.
private	dng	dng=1, Bank owned by private., dng =0 others.
state bank (persero). local government (BPD). private. foreign and joint venture banks.	dpe $dbpd$ dsw das	dng=1, Bank owned by private., dng =0 others. dpe=1 bank persero, dpe =0 others. $dbpd$=1, $dbpd$=0 others. dsw =1 private bank, dsw =1 other, das =1 own by foreign and combination foreign and domestic, das =0 others,
Credit	cr	Credit for investment, working capital, and consumption.
Expected DPK	$E\widehat{dpk}$	Obtained from the fitted value of the deposits equation.
Macroprudential policy	mp	The policy dummy is based on the implementation of the Loan-to-Value (LTV), RIM, and PLM policies. If one of these policies is implemented, then the dummy value is 1 if the policy is tight, zero if there is no policy, and -1 if the policy is loose.

Note: Central Statistics Agency (BPS), Source: Ministry of Finance (MoF), Source: Bank of Indonesia.

Furthermore, the estimated macroeconomic model is as follows[1]:

$$\hat{y}_t = \alpha_0 + \alpha_1 \hat{y}_{t-3} + \alpha_2 \hat{y}_{t+3} + \alpha_3 \left(\widehat{\imath^a}_{t-1} - \hat{\pi}_t\right) + \alpha_4 \hat{g}_{t-3} + \alpha_5 \hat{g}_{t-3} D\hat{y}N_{t-3} + \alpha_6 \dot{er}_{t-1} + u1_t \quad (2)$$

$$\pi_t = \beta_0 + \beta_1 \pi_{t-1} + \beta_2 \pi_{t+1} + \beta_3 \hat{y}_t + u2_t \quad (3)$$

$$\hat{\imath}_t = \gamma_0 + \gamma_1 \hat{\imath}_{t-1} + \gamma_2 (\pi_t - \pi_t^T) + \gamma_3 \hat{y}_t + \gamma_4 \widehat{er}_{t-1} + u2_t \quad (4)$$

Where $\hat{y}$ is the output gap, $\left(\widehat{\imath^a}_{t-1} - \hat{\pi}_t\right)$ or $\left(\widehat{\imath^a}_t - \hat{\pi}_{t+1}\right)$ is the difference between the deposit interest rate gap and the inflation gap (gap in real interest rates), $\hat{g}_t$ is the gap in government spending, $D\hat{y}N_t$ is a negative output gap dummy variable, $\dot{er}_t$ is monthly depreciation of the Rupiah against USD, π_t is inflation *yoy*, $\hat{\imath}_t$ is the gap in policy interest rates, $(\pi_t - \pi_t^T)$ is the difference between actual output and the inflation target, and $\widehat{er}_t$ is the gap of the Rupiah exchange rate per USD.

Meanwhile, to estimate deposits, the following equation is used:

$$\widehat{dpk}_{it} = \delta_0 + \delta_1 i^p_{i,t-1} + \delta_{20} i^p_{i,t-1} dcv_{i,t-1} + \delta_3 \widehat{dpk}_{i,t-1} + \delta_4 E\hat{y}_{it} + \delta_5 E\hat{\pi}_{it} + u4_{it} \quad (5a)$$

$$\widehat{dpk}_{it} = \delta_0 + \delta_1 i^p_{i,t-1} + \delta_{20} i^p_{i,t-1} dcv_{i,t-1} + \delta_{21} i^p_{i,t-1} dcv_{i,t-1} dng_{t-1} + \delta_3 \widehat{dpk}_{i,t-1} + \delta_4 E\hat{y}_{i,t} + \delta_5 E\hat{\pi}_{i,t} + u4_{i,t} \quad (5b)$$

$$\begin{aligned}\widehat{dpk}_{it} = {} & \delta_0 + \delta_1 i^p_{i,t-1} + \delta_{20} i^p_{i,t-1} dcv_{i,t-1} + \delta_{22} i^p_{i,t-1} dcv_{i,t-1} dbpd_{i,t-1} \\ & + \delta_{23} i^p_{i,t-1} dcv_{i,t-1} dsw_{i,t-1} + \delta_{24} i^p_{i,t-1} dcv_{i,t-1} das_{i,t-1} + \delta_3 \widehat{dpk}_{i,t-1} \\ & + \delta_4 E\hat{y}_{it} + \delta_5 E\hat{\pi}_{it} + u4_{it}\end{aligned} \quad (5c)$$

Essentially, equations (5a), (5b), and (5c) are identical. The difference lies in (5b), where we assess whether deposit insurance played a more significant role in non-government-owned banks during the crisis than in government-owned banks. Conversely, in equation (5c), the study examines whether there are disparities in the impact of deposit insurance on the deposit gap $\widehat{dpk}$ among state-owned banks, local government-owned banks or BPDs, private banks, and foreign and joint venture banks during the crisis.

Furthermore, to estimate the credit equation, the following equation (6) is used:

$$\begin{aligned}\widehat{cr}_{it} = {} & \vartheta_0 + \vartheta_1 \widehat{\imath^{cr}_{it}} + \vartheta_2 \hat{\imath}_{i,t-3} + \vartheta_3 E\hat{\imath}_t + \vartheta_4 E\widehat{dpk}_{it} + \vartheta_5 E\widehat{dpk}_{it} dcv_{it} + \vartheta_6 \widehat{dpk}_{it} \\ & + \vartheta_7 \widehat{dpk}_{it} dcv_{it} + \vartheta_8 \widehat{mp}_{it} + \delta_9 E\hat{y}_{i,t-3} + \delta_{10} \widehat{cr}_{i,t-1} + u5_t\end{aligned} \quad (6)$$

Equations (2), (3), and (4) are estimated using Ordinary Least Squares (OLS). Before estimation, stationarity tests were conducted using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. Ensuring the data's stationarity is essential to mitigate erratic regression (Gujarati & Porter, 2008). Subsequently, residual stationarity tests are performed post-estimation. If the residuals are stationary, it can be inferred that the regression residuals are normal, uncorrelated, and homoscedastic (Thomas, 1997).

[1] We modify model of Fahr and Fell (2017) by adding the idea by Muscatelli et al. (2004) who incorporate fiscal variables into IS, Galı & Gertler (1999) who include backward and forward-looking inflation (π_{t-1} and π_{t+1}) in PC, and Utama et al. (2022) who includes international and crisis variables into IS. We also add monetary policy rule as presented in Handa (2009: 358-430), and the monetary policy rule

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Estimating macroeconomic models is significant for validating the applicability of macroeconomic theories in the Indonesian context. Moreover, it is imperative to incorporate macroeconomic factors that influence deposit and credit behavior into models. Equations (5) and (6) are estimated using the Fixed Effects Model (FEM). Stationarity tests are conducted using the Levin, Lin & Chu (LLC), Breitung, Im, Pesaran and Shin (IPS), ADF – Fisher, and PP – Fisher methods. Ensuring stationarity of the estimated data is crucial for mitigating bias in regression. Subsequently, residual stationarity is assessed post-estimation.

Furthermore, in the deposits model, a Wald test is conducted to evaluate whether the coefficient on deposit insurance's impact during crises differs between non-government and government-owned banks (equation 5a) and to assess the disparity in the effect of deposit insurance across four types of banks.

RESULTS AND DISCUSSION

The first step in estimating the macroeconomic model involves testing the stationarity of the variables using the ADF and PP tests, as shown in Table 2. The results show that all variables used in the estimation are stationary. The economic model is estimated using a system of least squares equations. The estimation results are presented in Table 3 below. To ascertain the significance of the variables, a one-sided test is employed, guided by theoretical predictions to form directional hypotheses. This testing approach is crucial to validate the suitability of the macroeconomic model for Indonesia's economic conditions.

Table 2. The Stationarity Test of Macroeconomic Variables

Variable	ADF		PP	
	Constant	Constant, linear trend	Constant	Constant, linear trend
$\widehat{y_t}$	-5,3125*	-5,3017*	-4,6817*	-4,6745*
	(0,0000)	(0,0001)	(0,0001)	(0,0010)
$(\widehat{\iota^d}_{t-1} - \hat{\pi}_t)$	-3,4890*	-4,2809*	-2,7938*	-3,3519*
	(0,0091)	(0,0040)	(0,0606)	(0,0605)
$\hat{g}_t$	-4,3703*	-4,3599*	-9,8253*	-9,7664*
	(0,0004)	(0,0030)	(0,0000)	(0,0000)
$\dot{er}_t$	-12,5127*	-12,5130*	-14,8102*	-14,8140*
	(0,0000)	(0,0000)	(0,0000)	(0,0000)
π_t	-1,7926*	-3,3056*	-2,8198*	-3,5088*
	(0,3836)	(0,0679)	(0,0569)	(0,0406)
$\hat{\imath}_t$	-4,2738*	-4,2637*	-3,4184*	-3,3989*
	(0,0006)	(0,0042)	(0,0112)	(0,0537)
$(\pi_t - \pi_t^T)$	-3,7514*	-3,9564*	-3,4690*	-3,6181*
	(0,0039)	(0,0113)	(0,0096)	(0,0303)
$\widehat{er}_t$	-5,3961*	-5,3896*	-5,7187*	-5,7057*
	(0,0000)	(0,0001)	(0,0000)	(0,0000)

Note: Stat. value, ADF statistic or PP statistic; (P-Value); * Stationary.

The IS equation shows the expected output gap significantly influences the output gap, with both backward-looking and forward-looking expectations showing positive effects (α_1 and α_2 are positive). Fiscal policy effectively impacts the output gap (α_4 care positive) during periods of output below (recession) and above potential. The α_4 indicates that changes in the effectiveness of fiscal policy during a crisis are insignificant. Additionally, in line with theoretical predictions, actual interest rates hurt the output gap (α_3 is negative). A decrease in real interest rates increases output through heightened investment and aggregate demand. Finally, the positive and significant α_6 confirms the theoretical prediction that depreciation of the Rupiah against foreign currencies boosts exports and reduces imports, thereby increasing domestic aggregate demand and production.

Phillips Curve (PC) estimation confirms the theory. The coefficients on forward- and backward-looking inflation expectations are significantly positive for inflation. Likewise, the effect of the output gap on inflation is positive, although not significant.

Table 3. Estimation of Macroeconomic Model

	$\hat{y}_t$		π_t		$\hat{\imath}_t$
α_0	-0.0111	β_0	-0.0443	γ_0	-0.0051***
	(-0,2251)		(-0,5421)		(-2,5073)
α_1	0,4393***	β_1	0,5033***	γ_1	0,9020***
	(9,0853)		(18,1646)		(50,7377)
α_2	0,4790***	β_2	0,50446***	γ_2	0,0054***
	(10,0030)		(18,1081)		(6,6203)
α_3	-0,0163**	β_3	0,0015	γ_3	0,0048***
	(-1,7682)		(0,0376)		(2,4757)
α_4	0,3230**			γ_4	0,0753**
	(1,8529)				(1,7445)
α_5	-0,1923				
	(-0,7415)				
α_6	4,8861***				
	(2,7619)				
R^2	0.473		0.964		0.949
Adj. R^2	0.459		0.964		0.948
N	240		242		243
Determinant residual covariance		0.000176			
Stationarity test of residual:					
ADF	-8.5225*		-8.52246*		-5.12978*
PP	-6.3585*		-6.35852*		-48.6735*

Note: Coefficient (t-statistic) significant at *α=0.1, at **α=0.05, at ***α=0.01.

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Table 4. Stationarity Test

	Levin, Lin & Chu	Breitung	Im, Pesaran and Shin	ADF - Fisher	PP - Fisher
$\widehat{dpk_t}$	-14.068*	-6.839*	-12.621*	148.016*	146.562*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
i_t^p	-3.922*	-1.946*	-4.594*	35.711*	7.814
	(0.000)	(0.026)	(0.000)	(0.000)	(0.4518)
$\widehat{Ey}_t$	1.921	-5.215*	-4.616*	36.027*	143.271*
	(0.973)	(0.000)	(0.000)	(0.000)	(0.000)
$\widehat{E\pi}_t$	56.019	-12.208*	-24.712*	364.301*	73.683*
	(1.000)	(0.000)	(0.000)	(0.000)	(0.000)
$\widehat{cr}_t$	0.301	-3.405*	-6.696*	61.053*	65.415*
	(0.618)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: The value of the statistic (P-Value), * Stationary

The estimation of the monetary policy rule also confirms the theory. The positive and significant value γ_2 indicates that the Central Bank raises interest rates if inflation exceeds the target. Likewise, if the output gap is positive, indicating economic expansion, the Central Bank increases interest rates to control inflation. The Central Bank also responds positively to a gap in the Rp/USD exchange rate. If the Rp/USD exchange rate deviates from the trend (the Rupiah depreciates more than expected), the Central Bank will raise policy interest rates. The increase in interest rates is expected to increase capital inflows, which in turn improve the exchange rate. Table 3 also shows that the residuals from all equations are stationary and that the R2 values are relatively high. To estimate the deposits and credit model, we employ monthly panel data. Most of the stationarity test results concluded that the variables used are stationary. Consequently, the estimated equation does not yield spurious regression.

The fitted value results from the IS, PC, and monetary policy rule equations are used as expectation variables in the deposits and credit equations. Moreover, the estimated deposits equation in Table 5 reveals that deposit insurance affects the amount of the deposit gap in banking; the $c\delta_1$ is positive and significant. The impact of deposit insurance on deposits has become increasingly significant during COVID-19, as evidenced by the value δ_{20}, which is also positive and significant. The Wald test results in Table 7(a) show an increase in the influence of deposit insurance on total deposits, with the coefficient increasing from 0.0009 before January 2020 to 0.0029 from January 2020 to May 2023.

Table 5. Deposit Equation

	(a) $\widehat{dpk}$	(b) $\widehat{dpk}$	(c) $\widehat{dpk}$
δ_0	-0.0077*	-0.0077*	-0.0077*
	(-1.4053)	(-1.4048)	(-1.4034)
δ_1	0.0009*	0.0009*	0.0009*
	(1.2956)	(1.2952)	(1.2940)
δ_{20}	0.0020**	0.0017*	0.0018
	(2.0774)	(1.3682)	(1.1234)
δ_{21}		0.0007	
		(0.5111)	
δ_{22}			-0.0002
			(-0.1178)
δ_{23}			0.0001
			(0.0314)
δ_{24}			0.0012
			(0.5734)
δ_3	0.6873***	0.6869***	0.6867***
	(27.4702)	(27.4324)	(27.3888)
δ_4	0.0072***	0.0072***	0.0072***
	(3.2194)	(3.2177)	(3.2142)
δ_5	-0.0021	-0.0021	-0.0021
	(-1.0594)	(-1.0583)	(-1.057)
R^2	0.488	0.488	0.488
Adj. R^2	0.483	0.482	0.481
n	816	816	816
Test of Residual test			
LLC	-12.2643*	-12.2156*	-12.2393*
ADF-F	167.825*	166.975*	167.538*
PP-F	499.819*	499.666*	500.377*

Note: Coefficient, (t-statistic), significant at* α=0.1, at ** α=0.05, at *** α=0.01.

Table 6(b) shows that the estimation findings align with those in Table 6(a), indicating that deposit insurance affects the deposit gap, with its influence growing during the COVID-19 and post-COVID-19 periods. The Wald test results reveal that the impact of deposit insurance on non-government-owned banks was more pronounced during the crisis than on government-owned banks. The coefficient for the effect of deposit insurance during the crisis period on deposits is 0.0026 (significant at the 10% level), while for non-government-owned banks, it is 0.0033 (significant at the 5% level). These results confirm that depositors perceive government-owned banks as safer than non-government-owned banks. Deposit insurance has increased customers' confidence in government-owned banks and even more so in non-government-owned, private, foreign, and joint venture banks.

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Table 6. Wald Test for Deposit Equation

	(a) $\widehat{dpk}$	(b) $\widehat{dpk}$	(c) $\widehat{dpk}$
δ_1	0.0009*	0.0009*	0.0009*
	(1.2956)	(1.2952)	(1.2940)
$\delta_1 + \delta_{20}$	0.0029**	0.0026*	0.0027*
	(1.9723)	(1.5548)	(1.3860)
$\delta_1 + \delta_{20} + \delta_{21}$		0.0033**	
		(1.9981)	
$\delta_1 + \delta_{20} + \delta_{22}$			0.0024
			(1.2624)
$\delta_1 + \delta_{20} + \delta_{23}$			0.0028*
			(1.4188)
$\delta_1 + \delta_{20} + \delta_{24}$			0.0028
			(1.4188)*

Note: Coefficient, (t-statistic), significant at* α=0.1, at ** α=0.05, at *** α=0.01.

Table 7. Credit Equation

	$\widehat{cr}_{it}$		
ϑ_0	0.0035***	ϑ_6	0.2863***
	(2.8144)		6.3117
ϑ_1	-0.5567***	ϑ_7	0.0537
	(-4.9708)		0.4525
ϑ_2	-0.0045	ϑ_8	-0.0036***
	(-0.2505)		-2.7021
ϑ_3	0.1131	ϑ_9	0.0025**
	(4.0890)		2.2030
ϑ_4	0.6681***	ϑ_{10}	0.4324***
	(3.6576)		6.6432
ϑ_5	-0.4561		
	(-1.0448)		
R^2	0.750		
Adj. R^2	0.727		
n	120		
LLC	-8.24166*		
ADF-F	99.7221*		
PP-F	97.8072*		

Note: Coefficient significant at* α=0.1, at ** α=0.05, at *** α=0.01.

The estimation results in Tables 5(c) and 6(c) demonstrate the significant effect of deposit insurance during the crisis on state-owned, private, joint-venture, and foreign banks. Meanwhile, BPD shows no significant. These findings also corroborate those in

Table 7(b), which indicate that the coefficient for the effect of non-government-owned bank deposit guarantees on deposits exceeds that for government banks. Furthermore, the positive and significant effect of the output gap on deposits aligns with theoretical predictions. Conversely, though theoretically expected, the negative influence of inflation is not significant in its coefficient.

Table 7 presents the results of the credit equation estimation. The findings indicate that two variables, the macroprudential policy and the amount of third-party funds, which are influenced by deposit insurance, effectively impact credit. Conversely, monetary policy and expectations of monetary policy do not significantly affect credit. Although monetary policy tightening (observed at ϑ_2) and monetary policy expectations (observed at ϑ_3) are negative as theorized, they lack significance. Gaps in deposits and in deposit expectations positively and significantly affect the credit gap.

Similarly, tightening macroprudential policy decreases the credit gap, while easing policy increases it. Additionally, a credit gap in interest rates significantly negatively impacts the credit gap, as per theoretical predictions. Lastly, the expected output gap exhibits a significant positive effect on the credit gap. These results, indicating credit's pro-cyclicality, support previous studies by Bernstein et al. (2016), Ascarya et al (2016), Leroy and Lucotte (2019), Huizinga and Laeven (2019), and Cuestas et al. (2022).

CONCLUSION

The findings indicate that deposit insurance significantly enhances depositor confidence in both normal and recessionary periods, though its effect is more pronounced during economic downturns. By providing a sense of security to depositors, deposit insurance helps prevent massive withdrawals (bank runs), especially during periods of financial distress. The study further reveals that deposit insurance plays a more important role in maintaining depositor confidence in private banks compared to state-owned banks, as depositors generally exhibit higher baseline trust in government-owned institutions. The study also highlights the substantial influence of macroeconomic variables, such as the output gap and expectations, on deposits and credit. The output gap is shaped by fiscal policy, real interest rates—determined by nominal interest rates and inflation—and international factors.

Furthermore, expectations play a significant role in influencing deposit and credit behavior. Therefore, policies implemented by authorities—including monetary, fiscal, and deposit insurance institutions—must effectively manage expectations to maintain economic stability. Furthermore, the study also finds that bank deposit stability, along with macroprudential policies, plays a crucial role in shaping credit allocation. The study recommends strengthening deposit insurance institutions and enhancing coordination with fiscal, monetary, and macroprudential policies. Each authority is pivotal in preserving deposit and credit stability, ultimately contributing to the financial system's stability.

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Government Spending Efficiency in BRICS Countries: Implications for Indonesia's Accession

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ABSTRACT

Research Originality: This study assesses Indonesia's move to join the BRICS as a pragmatic economic strategy through an efficiency analysis and an empirical comparison. Data Envelopment Analysis (DEA) is used to measure government spending efficiency, and panel data analysis is used to compare fiscal performance across BRICS countries.

Research Objectives: The research seeks to analyze how government effectiveness (GE), corruption perception index (CPI), trade openness (TO), and industrial value added (IND) shape government spending efficiency (GSE) across BRICS countries during the 2000–2023 period.

Research Methods: A two-stage approach is used: DEA estimates fiscal efficiency, while panel regression identifies its determinants.

Empirical Results: Empirical findings reveal that Indonesia consistently maintained strong fiscal efficiency, outperforming several original BRICS members even prior to its accession. The determinants of efficiency varied between periods: from 2000 to 2009, GE, CPI, and TO positively influenced GSE, while IND had a negative association. In contrast, from 2010 to 2023, GE and TO exerted adverse effects.

Implications: These findings suggest that maintaining fiscal efficiency in Indonesia depends on enhancing governance quality and strengthening industrial competitiveness.

Keywords:
corruption; efficiency; government effectiveness; trade openness

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INTRODUCTION

Indonesia's accession to the BRICS group (Brazil, Russia, India, China, and South Africa) as a new member is a significant development for its economic and foreign policy. According to the World Bank (2024), BRICS accounts for over 40% of the world's population and 26% of global GDP, offering a significant alternative to the dominance of developed countries in the global economic landscape. With a nominal GDP of around US$1.4 trillion in 2023 and its status as a developing country with a large domestic market, Indonesia is considered to have the potential to strengthen the BRICS' position as an inclusive, dynamic economic bloc. Li (2019) argues that the accession of new countries to the BRICS creates strategic opportunities to strengthen national economies. This is particularly evident in the potential for increased foreign investment, expanded international trade and strengthened cooperation in sustainable development, infrastructure and the financial sector (Banday et al., 2021; Narayan & Bui, 2021; Soomro et al., 2022). BRICS provides Indonesia with access to infrastructure project financing and strengthens its domestic financial system. It also enables Indonesia to participate more actively in global financial governance, including through participation in multilateral financial institutions such as the New Development Bank (Suchodolski & Demeulemeester, 2018).

The opportunities offered by Indonesia's BRICS membership are significant, but optimizing these benefits depends heavily on the quality of fiscal governance and public spending efficiency, which must compete with those of other member countries (Adebayo & Samour, 2024). In the current global context, Indonesia is under increasing pressure from a range of issues, including post-COVID fiscal constraints and rising uncertainty driven by global geopolitical turmoil, including regional conflicts, economic bloc fragmentation, and tensions in the global supply chain. Furthermore, volatility in financial markets and the intensification of the climate crisis exacerbate the challenges of managing the state budget. In these circumstances, the government must not only increase investment in strategic sectors such as education, health, infrastructure, defense, and financial services, but also ensure that every rupiah spent delivers optimal and sustainable development (Rahayu et al., 2017; Salman et al., 2019).

Government spending efficiency (GSE) is defined as the extent to which budget resources produce optimal development outcomes (Atems, 2019; Cuadrado-Ballesteros & Peña-Miguel, 2024; Montes et al., 2019). In this context, spending on strategic sectors such as education, health, the military, and infrastructure should be evaluated not only by the amount spent, but also by how effectively these funds are used to stimulate economic growth and improve public welfare (Melton-Fant, 2023; Nguyen & Su, 2022). However, the reality is that high spending does not always lead to optimal development outcomes. For instance, according to World Bank data, Indonesia allocates 25.6% of its total national expenditure to education and health, yet still faces challenges regarding literacy and dropout rates, as well as disparities in health services across regions.

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Improving the efficiency of public spending depends not only on governments allocating budgets effectively, but also on accounting for various institutional and managerial factors that shape the quality of fiscal management. The effectiveness of government is determined by the extent to which public services are of a high quality, bureaucratic capacity is effective, political pressure is independent, and the formulation and implementation of policy is optimal.

According to Chen & Aklikokou (2021), effective government performance in the aforementioned functions is associated with enhanced oversight of the state budget, more efficient bureaucratic processes, and a reduced potential for fiscal leakage. In summary, it may be posited that a high level of government effectiveness is a significant indicator of the success of transparent and accountable state financial management. Furthermore, corruption levels are a significant indicator of the effectiveness of state expenditure. High levels of corruption have been shown to erode budget efficiency, resulting in funds intended for public interests not reaching their designated targets. In this context, the Corruption Perception Index (CPI) is one of the benchmarks for assessing the strength of a country's financial management, oversight and integrity systems (Pei et al., 2021; Wei, 2022).

GSE is a crucial aspect in evaluating a country's fiscal performance, especially amid fiscal constraints and demands for effective development (Afonso & Fraga, 2024; Aizenman et al., 2019; Puron-Cid & Rodríguez Bolívar, 2018; Zhao & He, 2024). Efficiency refers to the extent to which public budgets can be optimally converted into economic and social development outcomes without wasting resources (Albassam, 2020). In the context of the global economy, fiscal constraints have prompted many countries, including Indonesia and the BRICS countries, to review the efficiency of public sector spending to ensure fiscal sustainability and inclusive development (Ma & Qamruzzaman, 2022). The efficiency of the system is measured using Data Envelopment Analysis (DEA), a non-parametric, frontier-based technique that quantifies the relative efficiency of decision-making units (Lobo & Araujo, 2017; Munoz, 2016; Pula & Elshani, 2022).

The issue of GSE has become a critical one in global financial management. Afonso and Fraga (2024) found that, despite a significant increase in public spending across 20 Latin American countries during the 2000-2019 period, these expenditures remain inefficient. On average, these countries could achieve the same level of performance with a budget reduction of up to 27%. Conversely, if expenditure levels are maintained, governments can improve performance by 18%. Meanwhile, in 68 developing countries and 14 developed countries during the period 2006-2014, Montes et al. (2019) found that increased fiscal transparency plays an important role in reducing public debt levels and strengthening government effectiveness and spending efficiency. Consequently, an analysis of public spending efficiency must be supplemented by an examination of the external factors that influence it, encompassing both the institutional aspects of government and the structural characteristics of a nation's economy.

As indicated by previous literature, government effectiveness, which is defined as the quality of public services and the capacity of the bureaucracy to manage policies efficiently, has been demonstrated to contribute positively to increased fiscal transparency and accountability. This, in turn, has been shown to improve budget allocation efficiency (Benbitour et al., 2024; Saab et al., 2019). Conversely, elevated levels of corruption have been shown to impede the efficiency of expenditure, leading to resource waste and distorting fiscal decision-making (Wei, 2022). Furthermore, an open economic structure supported by a strong industrial sector is believed to promote fiscal efficiency through mechanisms of market discipline and increased national productivity (Mugoni et al., 2024; Sadowski et al., 2025). Recent studies have explored the relationship between government spending and the economy. However, most of these studies are limited to linear approaches that do not account for technical efficiency in the transformation of fiscal inputs into economic outputs. In the global economic landscape, particularly in the wake of Indonesia's accession to the BRICS, evaluating public budgetary efficiency has become increasingly imperative. The present study aims to analyze Indonesia's fiscal efficiency relative to that of the five BRICS member countries. The present study analyses data from 2000 to 2023, dividing this period into two distinct time frames: the period before the establishment of BRICS (2000 to 2009) and the period from the organization's inception in 2010 to 2023.

Indonesia's move to join the BRICS group represents a strategic policy choice with the potential to have long-term implications for economic cooperation and fiscal governance. This study aims to evaluate the efficiency of government spending in BRICS member countries and use this as a benchmark to assess Indonesia's fiscal performance. By positioning Indonesia within the efficiency frontier of BRICS countries, the study will provide empirical evidence to inform the development of Indonesia's fiscal strategy post-membership. We hypothesize that government effectiveness and corruption control, as reflected in the CPI score, positively impact GSE. Additionally, we suspect that an increase in industrial value added and trade openness in each country may be positively correlated with GSE in both BRICS countries and Indonesia.

METHODS

This study aims to analyze Indonesia's fiscal efficiency relative to the five original BRICS member countries during the 2000–2023 period. The selected period captures the long-term dynamics of fiscal efficiency following the post-Asian Financial Crisis recovery, alongside the institutional evolution and economic expansion of BRICS. This period encompasses several major global economic shocks, including the commodity boom, the 2008 global financial crisis, and the COVID-19 pandemic, which are highly relevant to changes in government spending efficiency (GSE).

Government spending efficiency is measured using the DEA approach, which was chosen for its ability to evaluate relative efficiency across countries without requiring the specification of a particular production function and to form an efficiency frontier

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based on the best performers. Furthermore, panel data regression is employed to examine the effects of institutional and structural factors, namely government effectiveness, corruption perception, trade openness, and industrial value added, on GSE. The division of the panel analysis into several sub-periods enables identification of the dynamics of changes in fiscal efficiency in line with the institutional development of BRICS, thereby providing a deeper understanding of the potential implications of BRICS membership for Indonesia's fiscal performance. The inputs are government expenditures on education, health, infrastructure, and the military. Meanwhile, the economic growth rate serves as the output variable. Furthermore, by adopting and modifying the econometric model (Adegboye & Akinyele, 2022; Chan et al., 2017), this study analyses the comparison of the influence of government effectiveness, corruption perception index, trade openness, and industrial value added on GSE in Indonesia with five BRICS members using panel data regression with the following model:

$$GSE_{it} = \widehat{\beta_0} + \widehat{\beta_1} GE_{it} + \widehat{\beta_2} CPI_{it} + \widehat{\beta_3} TO_{it} + \widehat{\beta_4} IND_{it} + \hat{e}_{it} \quad (1)$$

where GSE is the result of efficiency analysis using Max DEA, GE represents the government effectiveness score, CPI is the corruption index for each country, TO is trade openness, and IND is industrial value added. The data sources for this study were taken from the World Bank, the United Nations Conference on Trade and Development (UNCTAD), and the Stockholm International Peace Research Institute (SIPRI).

RESULTS AND DISCUSSION

Based on the DEA results reported in Table 1, Indonesia consistently exhibits higher government spending efficiency than BRICS member countries over the sample period. Indonesia attains efficiency scores equal to or close to the efficiency frontier in several years, indicating an optimal conversion of fiscal inputs into economic and social outputs. This empirical evidence suggests that, even prior to its formal BRICS accession in 2025, Indonesia's fiscal performance was comparable to, and in some periods exceeded, that of incumbent BRICS members.

This efficiency reflects the Indonesian government's ability to allocate and use public budgets in a targeted and productive manner, while also demonstrating relatively stronger fiscal resilience compared to several other BRICS member countries. In contrast, countries such as India and China, the two largest economies in BRICS that have been members since its establishment in 2009, show more volatile efficiency trends and have lagged Indonesia's achievements for many years. This indicates that the size of an economy does not always correlate directly with fiscal efficiency, and that stability and the effectiveness of fiscal governance are key factors that are more determinative in efficiency analysis.

Table 1. Result of Efficiency Analysis

Year	Brazil	Russian	India	China	South Africa	Indonesia
2000	0.9267	1	0.9429	0.8581	0.9863	1
2001	0.9383	0.8972	0.7959	0.8535	1	1
2002	0.9967	0.9035	0.7887	0.7863	1	1
2003	1	0.8908	0.7704	0.7429	0.9944	0.8381
2004	0.9623	0.8983	0.7592	0.7149	0.9484	0.9046
2005	0.9369	0.9031	0.7109	0.6821	0.9605	0.8822
2006	0.8953	0.8625	0.7307	0.6705	0.9219	0.8930
2007	0.8384	0.7795	0.7346	0.6326	0.9117	0.8765
2008	0.7831	0.7424	0.6856	0.5574	0.8705	0.9883
2009	0.8295	0.9280	0.6649	0.5270	0.9065	1
2010	0.7551	0.8289	0.6590	0.5265	0.9201	1
2011	0.7580	0.7943	0.5946	0.5176	0.8765	0.9457
2012	0.7696	0.7834	0.6052	0.5039	0.8688	0.8683
2013	0.7625	0.8176	0.6834	0.5098	0.8628	0.7211
2014	0.7813	0.8318	0.6813	0.5159	0.8731	0.7519
2015	0.8569	0.8731	0.7134	0.5330	0.8724	0.6676
2016	0.9670	0.8717	0.7624	0.5391	0.9221	0.9268
2017	1	0.7802	0.7386	0.5401	0.9265	0.9651
2018	0.9520	0.8017	0.7036	0.5376	0.9423	1
2019	0.9025	0.8224	0.7414	0.5415	0.9380	1
2020	0.8943	0.8561	0.7568	0.5332	1	0.9184
2021	0.8371	0.8266	0.6705	0.5455	1	0.9877
2022	0.8732	0.8594	0.6564	0.5441	0.9777	1
2023	0.9174	0.7907	0.6451	0.5478	1	1

Source: Output Max Dea (2025)

This finding is in line with Rambe et al. (2022), who state that Indonesia has an increasingly robust economic and fiscal management structure, supported by bureaucratic reforms, greater budget transparency, and stronger public institutions. This success is not only an indicator of good fiscal performance but also a positive signal to the international community that Indonesia deserves to be part of a strategic alliance of developing countries such as BRICS. As a new member, Indonesia will not only be a follower in this alliance but also has the potential to make a substantial contribution in shaping the direction of global economic cooperation among Southern countries. With its macroeconomic stability, large domestic market, and experience in fiscal reform, Indonesia can serve as a bridge between BRICS and ASEAN countries, while strengthening BRICS' position as an alternative to

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a more inclusive, multipolar global economic architecture. This finding is consistent with Chan et al. (2017), who emphasize the strategic importance of institutional strength and fiscal transparency in enhancing emerging economies' roles in global economic governance.

Table 2. Panel Data Regression Analysis 2000-2009

Variable	CEM		FEM		REM	
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error
C	2.834	0.208	10.833	0.519	2.965	0.178
GE	-0.220***	0.030	0.071***	0.025	-0.239***	0.036
CPI	0.007***	0.002	0.003***	0.001	0.008***	0.001
TO	-0.000	0.000	0.001**	0.000	-0.001	0.000
LOG(IND)	-0.084***	0.007	-0.383***	0.020	-0.090***	0.006
R^2	0.816		0.986		0.643	
Adj, R^2	0.799		0.983		0.611	
F-stat.	49.979		376.562		20.282	
Prob.(F-stat)	0.000		0.000		0.000***	

(1) Chow: *Cross-section* F (4,41) = 71.268; Prob. F = 0.000***
(2) Hausman: *Cross section random* $\chi^2(4)$ = 135.879; Prob. χ^2 = 0.000***

Source: Data processed (2025); Note: ***Significant at α = 0.01; **Significant at α = 0.05; *Significant at α = 0.10.

We found that during the period 2000-2009, government effectiveness, CPI, and TO had a positive effect on GSE in the five BRICS countries, while IND had a negative effect. Based on Table 2, GE had a positive effect on GSE across the five BRICS member countries during 2000-2009. A coefficient of 0.07 means that for every 1-point increase in the government effectiveness variable (z-score), GSE will increase by 0.07 basis points. Meanwhile, a 1-basis-point increase in the CPI score was found to increase GSE by 0.003. The trade openness variable was also found to have a positive effect on GSE with a coefficient of 0.0009. This means that if trade openness increases by 10%, GSE will become more efficient, increasing by 0.009 basis points. IND, which proxies the industrial value-added variable, has a negative effect on GSE with a coefficient of -0.383. Thus, when industrial value-added increases by 1%, GSE decreases by 0.0038 basis points.

In the second stage, the analysis results indicate that, after the establishment of BRICS, government effectiveness and TO had an effect on GSE. Meanwhile, CPI and IND had no effect on GSE. During 2010–2023 across the five founding BRICS countries, GE and trade openness were found to negatively affect GSE, with coefficients of -0.055 and -0.004, respectively. Thus, during that period, a 1-z-score increase in GE was found to reduce GSE by 0.06 basis points. Meanwhile, if trade openness increases by 10%, GSE will decrease by 0.04 basis points. This indicates that since the establishment of BRICS, their public spending efficiency has statistically declined when viewed through the lens of government effectiveness, the corruption perception index, trade openness,

and industrial value added. Furthermore, the absence of a significant influence of the corruption perception index (CPI) and industrial value added (IND) on GSE indicates that these variables have not yet become primary determinants of public spending efficiency within the BRICS context during that period.

Table 3. Panel Data Regression Analysis 2010-2023

Variable	CEM		FEM		REM	
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error
C	3.857	0.087	2.188	1.012	3.712	0.251
GE	-0.045***	0.012	-0.055***	0.016	-0.051	0.032
CPI	-0.001	0.001	0.001	0.002	-0.001	0.002
TO	-0.004***	0.001	-0.004***	0.001	-0.003***	0.001
LOG(IND)	-0.107***	0.002	-0.048	0.039	-0.103***	0.007
R^2	0.994		0.987		0.857	
Adj, R^2	0.994		0.985		0.849	
F-stat.	2,868.521		574.279		97.786	
Prob.(F-stat)	0.000***		0.000***		0.000***	

(1) Chow: *Cross-section* F (4,61) = 34.539; Prob. F = 0,000***
(2) Hausman: *Cross section random* $\chi^2(4)$ = 25.651; Prob. χ^2 = 0,000***

Source: Data processed (2025); Note: ***Significant at α = 0.01; **Significant at α = 0.05; *Significant at α = 0.10.

This finding is quite counterintuitive; improvements in governance and trade openness are expected to promote fiscal efficiency through more optimal resource allocation and increased productivity. This contradicts the Heckscher-Ohlin theory as presented in Salvatore (2019), which posits that countries will benefit from openness by specializing in sectors where they have comparative advantages, leading to greater economic efficiency. However, our findings support Banday et al. (2021), who argue that the expected gains from trade openness and governance reforms may not materialize uniformly across developing countries due to structural rigidities, institutional weaknesses, or unequal distribution of trade benefits.

In the context of geopolitics and the evolving global structure, this finding actually shows that external pressures and internal imbalances can reduce the efficiency of public spending. One explanation for this phenomenon is that, since its inception, BRICS has been seen as an alliance challenging the economic and political dominance of Western countries such as the United States, Canada, and Western European countries (Ma & Qamruzzaman, 2022; Banday et al., 2021). BRICS carries a narrative of resistance against the unipolar global order controlled by institutions such as the IMF and the World Bank (Adebayo & Samour, 2024). As a result, external pressures have emerged in the form of investment diversion, changes in global trade flows, and diplomatic barriers that

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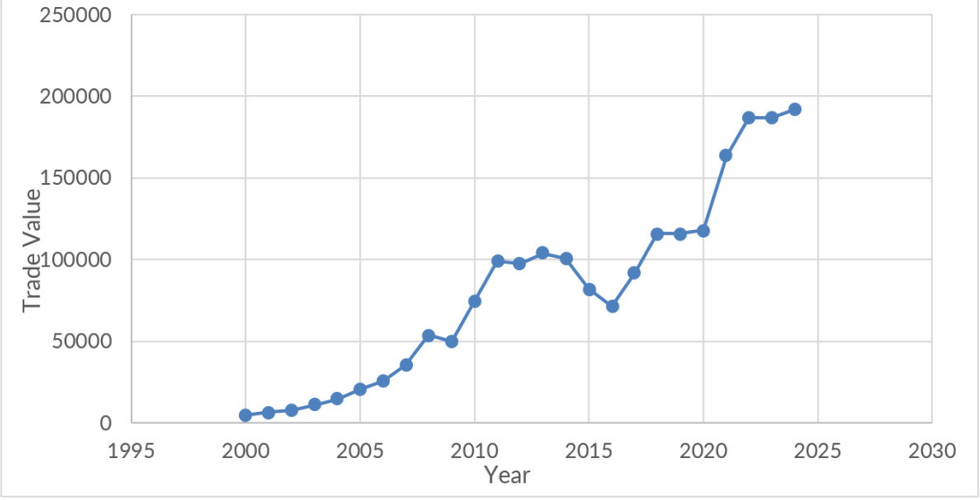
indirectly affect the internal economic performance of BRICS countries, including the efficiency of their fiscal policies.

Increased budgets amid ambitious development programs and BRICS multilateral cooperation are not always accompanied by efficient budget utilization, thereby negatively affecting GSE. Furthermore, although BRICS offers great potential for economic cooperation, the reality on the ground shows that its member countries still face complex structural and geopolitical challenges. Fiscal efficiency does not depend solely on economic openness or the quality of the bureaucracy in general, but is also influenced by the extent to which these countries can maintain internal stability, build market confidence, and navigate external pressures arising from shifts in the global power constellation. In this context, Indonesia's accession as a new BRICS member brings its own challenges and opportunities. With a relatively stable track record of fiscal efficiency, Indonesia has the potential to become a member that can maintain balance and make strategic contributions in promoting better fiscal governance among other BRICS countries.

Fig 1. International Trade Between Brazil & BRICS (Million US$)



Source: UN Comtrade (2025)

Figure 1 illustrates the trend in international trade relations between Brazil and the other four BRICS member countries over a considerable period, reflecting increasingly intensive economic cooperation. A substantial increase is particularly evident after the official formation of BRICS in 2009. The establishment of this economic platform provides a significant incentive for member countries to enhance trade, investment, and other strategic cooperation through bilateral and multilateral channels.

This increase in intra-BRICS trade indicates a new orientation in global economic relations, in which developing countries are beginning to forge closer cooperation as an alternative to the economic dominance of developed countries. In this context, Brazil and other BRICS countries have succeeded in expanding export and import volumes, sharing technology, and building mutually beneficial supply networks. Interestingly, although the

regression results in this study indicate that trade openness has a negative impact on public spending efficiency during the period of BRICS' establishment, this phenomenon cannot be understood in simple terms. The negative effect of trade openness on public spending efficiency reflects structural challenges in managing the impact of global trade outcomes on national budgets, not that international trade is inherently harmful. On the contrary, increased bilateral cooperation opens up significant opportunities to indirectly enhance fiscal efficiency through investment, innovation, and economic diversification.

Table 4. PAM Government Spending Efficiency Indonesia 2000-2023

GSE_t = 25.9619 + 0.4631 GE_t + 0.0201 CPI_t + 0.0003 TO_t – 0.9849 $LOGIND_t$ + 0.4735 GSE_{t-1} (0.0041) (0.0615) (0.9378) (0.0157) (0.0117)
R^2 = 0.6238; Adj. R^2 = 0,5131; *F* statistic = 5.636565; Prob. *F* = 0.003049
(1) Residual Normality (Jarque-Bera) | JB = 0.5704; Prob. JB = 0.7518 (2) Autocorrelation (Breusch-Godfrey) | χ^2= 2.707119; Prob. χ^2 = 0.2583 (3) Heteroscedasticity (White) | χ^2 = 8.263961; Prob. χ^2 = 0.1423

Source: Data processed (2025)

In Indonesia, during the period 2000-2023, we found that government effectiveness has a positive and significant influence on the efficiency of government spending, with a coefficient of 0.8796. This finding is consistent with the literature that emphasizes the central role of bureaucratic quality, institutional capacity, and policy implementation capabilities in improving fiscal efficiency, particularly in developing countries (Nguyen & Su, 2022). These studies show that strengthening public institutions enables more targeted allocation of fiscal resources and reduces structural inefficiencies in government spending. In the Indonesian context, these results reinforce the argument that institutional reform is a key prerequisite for improving sustainable fiscal performance. The finding that the corruption index has a positive effect on government spending efficiency is also consistent with previous studies showing that controlling corruption reduces budget leakage and increases the effectiveness of public spending (Benbitour et al., 2024). The positive coefficient of 0.0382 indicates that improvements in perceptions of governance and the integrity of public institutions directly optimize budget use, particularly by increasing efficiency in the procurement and distribution of state spending. These results reinforce the findings of Chan et al. (2017), which confirm that fiscal transparency and the strengthening of supervisory institutions are key factors in enhancing developing countries' role in global economic governance.

Conversely, the significant negative effect of industrial value added on government spending efficiency is not entirely in line with theoretical expectations or some previous empirical findings. Several studies argue that industrialization can improve fiscal efficiency by expanding the tax base and creating economic value added (Xiu, 2025). However, the results of this study are closer to findings indicating that fiscal intervention in the industrial sector is not always efficient when faced with misdirected subsidies, policy distortions, or limited industrial absorption capacity (Raihan et al., 2026). Thus, these

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negative findings indicate that fiscal allocation to Indonesia's industrial sector has not been fully translated into greater government spending efficiency.

Furthermore, the insignificant effect of trade openness on government spending efficiency is inconsistent with previous literature. Several studies have found that increased trade openness can encourage fiscal discipline and improve spending efficiency by creating greater competition and market pressure (Banday et al., 2021; Soomro et al., 2022). However, the results of this study are consistent with studies emphasizing that the benefits of trade openness for fiscal performance depend heavily on export structure, diversification levels, and integration into the global value chain. In Indonesia, the dominance of primary commodity exports and the limited participation of small businesses in international trade may explain the weak transmission of trade openness to government spending efficiency.

The findings demonstrate that the determinants of fiscal efficiency within BRICS are dynamic and highly dependent on institutional evolution, economic integration, and shifts in the global economic environment. The changes in the direction and significance of several explanatory variables between the pre- and post-BRICS periods indicate that fiscal efficiency in emerging economies cannot be explained solely by conventional governance indicators, but must also be interpreted within the broader framework of structural transformation and external economic exposure (Putra et al., 2025; Montes et al., 2019).

Indonesia's decision to join BRICS can be interpreted as a strategic economic response aimed at strengthening long-term fiscal resilience and economic sustainability amid increasing global uncertainty (Suchodolski & Demeulemeester, 2018). As a coalition of major emerging economies with complementary economic structures and expanding market potential, BRICS offers an alternative framework for South–South economic cooperation that is less reliant on conventional Western-led institutions. Indonesia's participation in BRICS may facilitate export market diversification, strengthen investment partnerships, and expand access to high-growth emerging markets (Ma & Qamruzzaman, 2022).

From a fiscal perspective, deeper engagement within BRICS may help improve public spending efficiency through several important channels. Expanded trade and investment cooperation can stimulate domestic economic activity and broaden the tax base, thereby strengthening the government's revenue capacity. Greater economic diversification may also reduce vulnerability to external shocks arising from excessive dependence on a limited number of trading partners and global financial centers. Institutional cooperation within BRICS further enables the exchange of development experience, infrastructure financing mechanisms, and policy innovation that may support more efficient fiscal governance (Soomro et al., 2022).

Indonesia's participation in BRICS may also strengthen its bargaining position within the global economic architecture, particularly in negotiations on trade governance, development financing, and the reform of international financial institutions. This becomes increasingly relevant in the context of persistent global volatility, where emerging economies require more flexible frameworks for cooperation that accommodate domestic development priorities and fiscal needs (Adebayo & Samour, 2024). Empirical findings show that

integration within BRICS does not automatically lead to improved fiscal efficiency. The negative relationship between trade and government spending efficiency in the post-2010 period suggests that increasingly intensive global economic integration is also accompanied by heightened vulnerability to commodity price volatility, financial market instability, and disruptions to global supply chains. In developing countries, these conditions can intensify pressure on governments' fiscal capacity, particularly when they must respond to external shocks by adopting expansionary fiscal policies to maintain domestic economic stability. This phenomenon has become increasingly relevant following the 2008 global financial crisis and the COVID-19 pandemic, which drove a significant increase in public spending across various BRICS nations (Aizenman et al., 2020).

From this perspective, Indonesia's decision to join BRICS can be understood as a long-term economic strategy to strengthen fiscal resilience and expand the scope for international economic cooperation. However, the economic benefits of BRICS membership will not be realized automatically without adequate domestic capacity. The findings of this study confirm that institutional quality, macroeconomic stability, and the government's ability to design adaptive fiscal policies remain key factors in determining the efficiency of government spending. Therefore, Indonesia's involvement in BRICS should be viewed not merely as a geopolitical and diplomatic move, but also as part of a broader economic transformation strategy to strengthen fiscal sustainability, enhance the competitiveness of national industry, and reinforce long-term economic resilience amid an increasingly multipolar and uncertain global economic landscape.

CONCLUSION

This study finds that government spending efficiency (GSE) among BRICS countries exhibited dynamic patterns during the 2000–2023 period, with Indonesia demonstrating relatively more stable and superior fiscal efficiency compared to several original BRICS members, even prior to its formal accession. The empirical findings reveal that during the pre-BRICS period (2000–2009), government effectiveness, the corruption perception index, and trade openness had a positive effect on fiscal efficiency, whereas industrial value added showed a negative effect. In contrast, during the post-BRICS period (2010–2023), government effectiveness and trade openness were found to negatively affect GSE, while corruption perception and industrial value added no longer exerted significant effects. The findings indicate that the determinants of fiscal efficiency in BRICS economies are highly dynamic and increasingly shaped by broader global economic uncertainty, institutional transformation, and geopolitical developments following the establishment of BRICS.

Indonesia's accession to BRICS therefore reflects not only a geopolitical strategy, but also a pragmatic economic initiative aimed at strengthening long-term fiscal resilience and economic competitiveness. Indonesia's relatively strong fiscal efficiency performance indicates its readiness to contribute to BRICS economic cooperation. However, the findings suggest that maintaining fiscal efficiency in Indonesia depends on enhancing governance quality and strengthening industrial competitiveness. Improving bureaucratic

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effectiveness, promoting adaptive fiscal policies, and strengthening productive industrial sectors remain essential to maximizing the potential benefits of BRICS membership and supporting sustainable economic stability in the long run.

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State Political Risk and Industrial Performance: Evidence from Sub-Saharan Africa

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ABSTRACT

Research Originality: This study offers an original external instrumental variable (IV) analysis of the causal link between state political risk and industrialization in Sub-Saharan Africa, using constitutionally fixed executive elections as a novel instrument.

Research Objectives: This study tests the hypothesis that state-sanctioned violence negatively impacts industrial growth in Sub-Saharan Africa.

Research Methods: This study employs a Two-Stage Least Squares (2SLS) model on a panel of 30 African countries (2000–2023). State political risk is measured by the Political Terror Scale, which captures state-sanctioned violence and is instrumented by fixed election timing. Industrial value-added growth is the dependent variable.

Empirical Results: We find no statistically significant causal effect of state-sanctioned violence on industrial growth. This null result is robust across 2SLS, Limited Information Maximum Likelihood(LIML), and GMM estimators.

Implications: Industrial policy in moderately unstable African contexts should prioritize core economic and regulatory constraints over broad political risk mitigation. The findings point to significant industrial resilience.

Keywords:
political risk; industrial growth; instrumental variables; fixed elections; African economies

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INTRODUCTION

Industrialization has long been regarded as the cornerstone of structural transformation and sustained economic development worldwide (Fotio & Karim, 2024). Nonetheless, Sub-Saharan Africa's industrial development presents a persistent and troubling paradox of profound concern to development economists and policymakers. The continent's share of global manufacturing declined from approximately 3% in the 1970s to less than 2% by 2023, placing it at the bottom of the global value chain (Boumbouya & Ocran, 2025). As of 2022, manufacturing value added per capita in Sub-Saharan Africa stood at just US$207, compared with a global average of US$1,879, while the sector accounted for only 10.4% of GDP and 7.4% of total employment (Santiago et al., 2024). This industrial stagnation, described as "premature deindustrialization" (Rowthorn & Rowthorn, 2024), occurs despite the historical role of industrialization as a universal driver of modern economic progress (Gollin & Kaboski, 2023; Lewis, 2024). It persists alongside notable aggregate economic growth in the 21st century, thereby presenting a central puzzle for scholars and policymakers (Fosu & Twumasi, 2022).

The dominant explanatory framework in political economy attributes Africa's industrial struggles primarily to state political risk, also known as political terror or state-sanctioned violence, and to broader institutional weaknesses. Throughout this article, we use the term state-sanctioned violence to refer specifically to political repression, torture, killings, and disappearances perpetrated by government agents, as measured by the Political Terror Scale. This form of political risk is distinct from other forms of instability, such as coups, civil wars, or criminal violence. Rooted in New Institutional Economics, this view holds that state-sanctioned violence creates profound uncertainty by undermining property rights and disrupting production cycles, thereby deterring the long-term, irreversible investments essential for industrialization (Acemoglu et al., 2014; Acemoglu & Robinson, 2012). This macro-institutional logic is further complemented by microeconomic theories of investment under uncertainty. These theories posit that state-sanctioned violence dramatically increases the perceived risk of expropriation, leading firms to postpone capital commitments. This behavior is often described as the *rational option value of waiting*, which can aggregate into sector-wide stagnation (Wan et al., 2024; Baker et al., 2016). Recent firm-level studies further suggest that industries characterized by higher asset fixity and greater dependence on complex supply chains are particularly sensitive to such disruptions (Akcigit et al., 2021; Inoue & Todo, 2011).

Empirical studies have largely reflected these theoretical expectations, establishing a robust negative correlation between various measures of political instability and economic performance, both in broad cross-country samples and in studies focusing on Africa (Dalyop, 2019; Fosu & Twumasi, 2022). A growing consensus further suggests that industrial sectors, due to their reliance on fixed capital and complex supply chains, are disproportionately vulnerable to such risks (Inoue & Todo, 2011; Collier & Venables, 2012; Sugihara, 2018) Studies such as those by Dalyop (2019) and (Lompo et al., (2025) have cemented the view of instability as a primary impediment to growth, while more

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recent work extends this perspective to sectoral analyses (Bodea et al., 2016). Nonetheless, a parallel and evolving strand of literature on African political economy complicates this narrative. Research highlights the adaptability of firms operating within hybrid governance systems, where informal networks, kinship ties, and flexible operational strategies can buffer enterprises against macro-political shocks (Williams, 2021; Diaz-Cayeros, 2026). Furthermore, insights into the political geography of development suggest that ruling elites often have strong incentives to spatially insulate vital economic enclaves, especially those generating state revenue, from the violence used to consolidate power elsewhere (Fambeu, 2024). This creates a potential disconnect between national measures of terror and localized industrial outcomes (Berman et al., 2017).

The literature, however, is marked by unresolved tensions that motivate this study and render the topic enduringly interesting. A methodological tension persists where a fundamental endogeneity problem confounds well-documented correlations. According to Wiebusch & Aniekwe (2019), poor industrial performance may itself fuel political instability through unemployment and social discontent, leaving causal inference elusive. Most existing studies rely on observational methods that are vulnerable to reverse causality, with few attempting causal identification (Tuki, 2024; Radil, 2026). Also, there is a rigidity in measurement, with many studies relying on broad governance indices that conflate political violence with unrelated institutional features, thereby obscuring the specific channel through which violence might matter (Zallé, 2017). Moreover, the substantive theoretical tension is sharpening, whereby while institutional theories strongly predict that political instability will harm industrial growth, evidence of African resilience attributed to hybrid governance, spatial insulation, and elite strategies of selective protection challenges this deterministic view (Raleigh, 2016; Radil, 2026) This tension raises a pivotal, unanswered question: Is the observed negative correlation between state violence and industrial outcomes causal, or is it an artifact of endogenous forces and masked by resilience mechanisms?

The literature, however, carries several unresolved tensions that motivate this study. A well-documented correlation between political instability and poor economic performance exists, yet it remains confounded by a fundamental endogeneity problem. As Wiebusch and Aniekwe (2019) observe, poor industrial performance may itself fuel political instability through unemployment and social discontent, leaving causal inference elusive. Most existing studies rely on observational methods that are vulnerable to reverse causality, with few attempting causal identifications. Whether political terror causes industrial stagnation, or whether stagnating economies appear more politically unstable, therefore remains an open question (Tuki, 2024).

Adding to this concern, much of the existing evidence suffers from a measurement problem. Many studies rely on broad governance indices that bundle state-sanctioned violence together with unrelated institutional features such as regulatory quality or bureaucratic effectiveness (Che et al., 2015; Knack & Keefer, 1995; Handoyo, 2023). This aggregation risks obscuring the specific channel through which political terror might

matter for industrial outcomes (Zallé, 2017). A clear test requires isolating state-sanctioned violence from other governance dimensions.

A further theoretical tension sharpens the puzzle. While institutional theories strongly predict that political instability will harm industrial growth, emerging evidence of African resilience challenges this deterministic view. Firms operating within hybrid governance systems, where informal networks and kinship ties buffer enterprises from macro-political shocks, may be less vulnerable than assumed (Lifongo, 2026). Ruling elites also have strong incentives to spatially insulate vital economic enclaves from the violence used to consolidate power elsewhere (Fambeu & Tsambou, 2025). These possibilities raise a pivotal question: is the observed negative correlation between state violence and industrial outcomes truly causal, or an artifact of endogeneity masked by resilience mechanisms?

This study directly confronts these interconnected gaps. To our knowledge, it offers the first rigorous external instrumental variable analysis of the causal relationship between state-sanctioned political violence and industrialization in Sub-Saharan Africa. The novelty rests on three elements. We address endogeneity directly using constitutionally fixed executive elections as an instrument, thereby moving beyond correlation. We isolate state-sanctioned violence using the violence-specific political terror scale rather than broad governance indices. Moreover, we explicitly test the institutional theory prediction against the competing hypothesis that African industrial sectors are resilient to moderate political instability.

A null finding would not merely contradict conventional wisdom. It would compel a significant recalibration of theory, redirecting scholarly and policy focus toward the specific institutional functionalities and binding economic constraints that dominate the investment landscape in contexts of moderate instability (Boumbouya & Ocran, 2025; Zallé, 2017; Fotio & Karim, 2024). A significant negative finding would instead validate dominant institutional theories and strengthen the case for political risk mitigation as an industrial policy priority. Either outcome offers a causally identified contribution to both academic debates on the institutional prerequisites for development and the strategic design of effective industrial policy in contemporary Africa.

METHODS

This study utilizes an unbalanced panel dataset covering 30 Sub-Saharan African countries over 23 years from 2000 to 2023. The year 2000 marks the beginning of the modern Political Terror Scale (PTS) data, with consistent country coverage, and follows the wave of democratization and political reforms across many African countries in the late 1990s. The endpoint 2023 represents the most recent year with complete data across all variables at the time of analysis. Countries were selected based on data availability for constitutionally fixed executive elections and for complete model variables, thereby ensuring broad regional representation (Acemoglu et al., 2014; Lompo et al., 2025). Data were compiled from multiple sources, including industrial and macroeconomic variables from the World Bank's World Development Indicators (WDI); state-sanctioned violence

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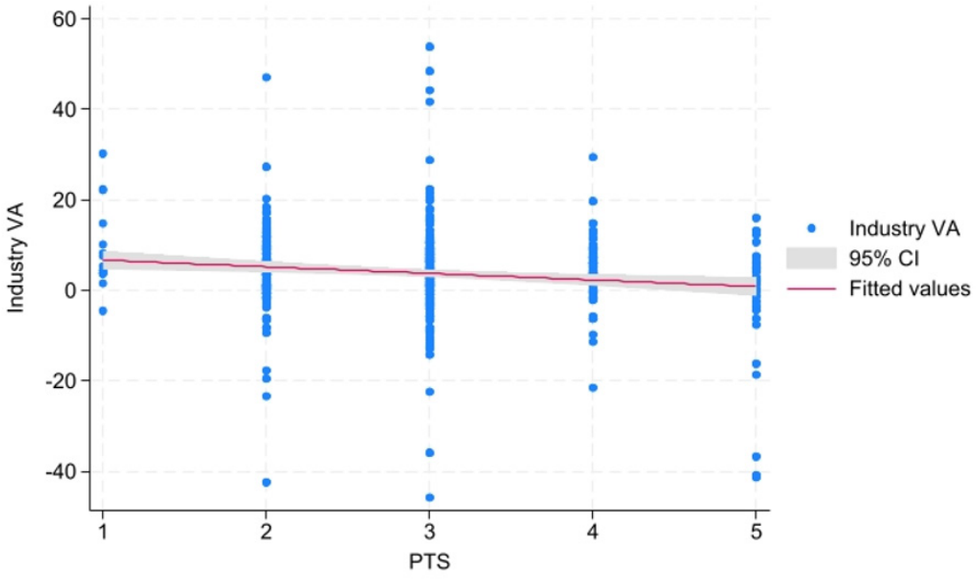
from the Political Terror Scale (PTS); election timing from the Database of Political Institutions (DPI) and National Elections Across Democracy and Autocracy (NELDA) dataset (Hyde & Marinov, 2012); and governance indicators from the Worldwide Governance Indicators (WGI). After listwise deletion to maintain consistency, the final sample comprised 373 country-year observations. All continuous variables were winsorized at the 1st and 99th percentiles to mitigate the influence of extreme outliers (Autor et al., 2008; Gentzkow et al., 2011). Figure 1 presents a preliminary scatter plot of this relationship after Winsorization, providing a visual check of the raw correlation before introducing multivariate controls and addressing endogeneity. The figure indicates a weakly negative relationship between Political Terror and Industry Value Added. The large dispersion of points at each PTS level highlights substantial variation in industrial performance, and the wide 95% confidence interval suggests that this bivariate relationship is imprecisely estimated.

Figure 1. Industrial Growth and Political Terror with Fitted Line and 95% Confidence Interval



Source: author's calculation

The dependent variable is the annual growth in industrial value added (VA), which captures the pace of industrial expansion (Fotio & Karim, 2024; Rowthorn & Rowthorn, 2024). The key independent variable, state political risk, is measured using the PTS, an ordinal scale (1–5) focusing specifically on state-sanctioned violence. The instrumental variable is a binary indicator for constitutionally fixed executive elections, which provides plausibly exogenous variation in political terror during electoral periods (Cox et al., 2019). Control variables include GDP growth, gross capital formation, export and import growth, broad money, and all six disaggregated WGI dimensions to account for economic fundamentals and institutional quality. Table 1 presents detailed definitions and measurement descriptions of all operational variables.

Our baseline econometric model is a two-way fixed effects panel regression:

$$Indus_{it} = \beta_0 + \beta_1 PTS_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where $Indus_{it}$ is industrial value-added growth in country i and year t; PTS_{it} is the Political Terror Score measure. X_{it} is the vector of control variables including GDP growth, exports, imports, gross capital formation, broad money, and all six WGI indicators (Voice and Accountability, Political Stability, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption), and ε_{it} is the characteristic error term. The six WGI indicators capture social infrastructure and property rights and collectively reflect overall institutional quality. To address the endogeneity of political terror, we estimate a Two-Stage Least Squares (2SLS) model with two-way fixed effects. Two-way fixed effects are used to control for unobserved, time-invariant country-specific characteristics and common time shocks that affect all countries (De Chaisemartin & d'Haultfoeuille, 2020; Wooldridge, 2025).

Table 1. Operational Variables

Variables	Definitions	Measurements	Sources	References
Industrialization	Total output of mining, manufacturing, construction, and utilities.	Industry VA (% GDP)	WDI	(Dinh, 2023; Rodrik, 2016, Fotio & Karim, 2024)
	Tracks the output of factories and processing plants	Manufacturing VA(% GDP)	WDI	
State Political Risk	Levels of political violence, state repression, and human rights violations	PTS	Amnesty International	(Gibney, 2020)
Economic Performance	Annual percentage change in the total monetary value of all final goods and services produced	GDP growth	WDI	(Ahuja & Pandit, 2020; Gootjes et al., 2024)
Investment	Total new physical assets added to an economy's productive capacity	Gross Capital Formation (% GDP)	WDI	(Borio et al., 2017; Furceri & Zdzienicka, 2012; Kose & Ohnsorge, 2021))
Institutions (Including Social Infrastructure & Property Rights)	Quality of public services, bureaucracy, market friendly policies , legal framework, integrity of institutions, institutional durability, and democratic institutions	All 6 WGI Indicators	WGI	(Kaufmann, 2024)
Financial depth and credit availability	Reflect the overall size of the financial system relative to economic output	Broad Money (% of GDP)	WGI	(Abid et al., 2016; Ehigiamusoe et al., 2025; Hassan et al., 2011)
Trade Dynamics	Foreign demand of domestic goods, technology & inputs.	Exports(% GDP)	WGI	(Fotio & Karim, 2024)
	Domestic demand for foreign goods, technology & inputs	Imports(% GDP)	WGI	(Fotio & Karim, 2024)
Instrument(IV)	An exogenous shock that causes measurable spikes in political risk	Fixed executive elections	NELDA & DPI	(Authors's own contribution; Hyde & Marinov, 2012)

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The first stage regresses the PTS score on the instrumental variable (fixed elections) and all controls as shown here:

$$PTS_{it} = \pi_0 + \pi_1 executive_{it} + \pi_2 X_{it} + \mu_i + \lambda_t + \vartheta_{it} \quad (2)$$

The second-stage regression then uses the predicted values of political terror, $\widehat{\text{PTS}}$, from the first stage:

$$Indus_{it} = \alpha + \rho \widehat{PTS} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

where Indus_{it} is industrial value-added growth in country i and year t, $\widehat{\text{PTS}}$ is the exogenous political terror, ρ is the causal effect of political terror on industrialization, X_{it} is the same vector of control variables, μ_i and λ_t are country and year fixed effects, and ε_{it} is the error term.

We validate the IV strategy through several checks. Instrument relevance is confirmed by a first-stage F-statistic meeting the conventional threshold of greater than or equal to 10 (Andrews et al., 2019). Weak-instrument-robust inference is conducted using the Anderson-Rubin test (Andrews et al., 2019). Results are further verified using Limited Information Maximum Likelihood (LIML) estimators, which are robust to weak instruments (Andrews et al., 2019). We also employ a Two-Step System GMM estimator to address dynamic panel bias (Kripfganz, 2019), and use manufacturing value-added growth as an alternative dependent variable. All estimations were performed in Stata 18 using the ivreg2 package(Andrews et al., 2018; Young, 2024), with standard errors clustered at the country level.

RESULTS AND DISCUSSION

Table 2 presents summary statistics for the variables used in the analysis, based on 373 country-year observations across 30 Sub-Saharan African countries from 2000 to 2023. Industrial value-added growth averages 7.25% annually, with a standard deviation of 6.97 percentage points, indicating considerable volatility in industrial performance. The range spans from –45.79% to 53.85%, reflecting sharp contractions and rapid expansions. The PTS averages 2.98, with a standard deviation of 0.91, suggesting that the average country-year exhibits state-sanctioned violence near the upper bound of moderate intensity. The six WGIs show consistently negative mean values, ranging from –0.58 to –0.81, confirming the sample's challenging institutional environment. Economic fundamentals reveal a foundation for growth, with GDP growth averaging 5.31% and gross capital formation averaging 23.46% of GDP. Export and import growth averages are robust at 7.52% and 7.25%, respectively, signaling active engagement in international trade despite notable volatility, as reflected in standard deviations of 16.06% and 18.01%, respectively. Financial depth, proxied by broad money as a percentage of GDP, averages 25.91%, suggesting moderate credit availability in the financial system. Collectively, these figures depict a sample characterized by both economic dynamism and persistent institutional constraints, providing a relevant context for examining the relationship between political risk and industrialization.

We employed an IV strategy to disentangle correlation from causation between state political risk and industrialization in Sub-Saharan Africa. Using constitutionally fixed executive elections as an instrument, justified by established patterns of electoral violence, the first-stage regressions yield F-statistics of 10.37 (2SLS) and 12.10 (LIML), confirming instrument relevance while indicating moderate strength (Andrews et al., 2019). This approach addresses the endogeneity concerns that plague earlier correlational studies (Acemoglu et al., 2014). While standard OLS models show a significant negative association between political terror and industrial growth, consistent with broader literature (Aisen & Veiga, 2013; Barro, 1991), the IV estimates render this relationship statistically insignificant. This divergence suggests that the observed correlation likely reflects reverse causality or omitted variables rather than a genuine causal effect of state violence on industrial performance during the period 2000-2023. We obtain consistently similar results when using manufacturing value added as an alternative measure of industrialization (results not shown). Table 3 presents results from four estimation methods, with industry value-added as the dependent variable.

Table 2. Summary Statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
Industry VA	373	7.250	6.970	-45.794	53.846
Manufacturing VA	373	6.650	10.792	-43.840	75.168
Political Terror	373	2.981	0.910	1	5
GDP Growth	373	5.312	4.408	-36.392	19.675
Gross Capital Formation	373	23.460	9.023	1.097	76.782
Exports	373	7.522	16.055	-52.056	84.440
Imports	373	7.250	18.007	-57.089	210.259
Control of Corruption	373	-0.758	0.498	-1.646	0.776
Government Effectiveness	373	-0.811	0.465	-1.881	0.668
Voice and Accountability	373	-0.641	0.581	-1.100	0.596
Political Stability	373	-0.570	0.698	-2.729	1.201
Regulatory Quality	373	-0.640	0.467	-2.202	0.583
Rule of Law	373	-0.701	0.484	-1.870	0.457
Broad Money	373	25.910	10.811	6.476	59.709
Fixed Executive Elections	373	0.179	0.380	0.000	1.000

In contrast to the null finding for political terror, economic fundamentals and specific institutional factors emerge as robust drivers of industrialization. GDP growth, physical investment, and financial depth show consistently positive and significant effects across specifications. Notably, Regulatory Quality stands out among governance indicators, underscoring the salience of predictable, market-oriented regulation over broader measures

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of political instability (Acemoglu & Johnson, 2005). The stability of these coefficients, alongside the volatile political terror estimate under IV estimation, indicates that binding constraints on industrial expansion in this context lie more in structural economic conditions and functional institutional capacity than in fluctuations in state-sanctioned violence. This insight aligns with growth diagnostics frameworks that prioritize the most immediate barriers to investment.

To ensure that our null finding is not an artifact of weak identification, we employed the Anderson-Rubin (AR) test, which provides valid inference regardless of instrument strength (Andrews et al., 2019). The AR test yields a chi-squared (χ^2) statistic of 1.61 (p = 0.2045) (Table 4). This small χ^2 value indicates little departure from the null hypothesis of no effect. The corresponding 95% confidence interval [-1.64, 0.46] comfortably includes zero, confirming the absence of a statistically detectable causal relationship between state political terror and industrial growth. This result confirms that weak instruments do not drive the insignificant relationship; rather, it reflects a genuine absence of a systematic causal effect in our sample and period.

Table 3. Multiple Results for Industry VA

	OLS	OLS(FE)	2SLS(IV)	LIML(IV)
Political Terror	-0.126***	-0.1140**	-0.560	-0.241
GDP Growth	0.146***	0.1590***	0.164***	0.0430**
Gross Capital Formation	0.004	0.0272**	0.025**	0.0260***
Exports	0.008**	0.0090**	0.010***	0.0010
Imports	-0.012***	-0.0111*	-0.012**	0.0090***
Control of Corruption	0.141	-0.3310	-0.543	-0.3570
Government Effective	-0.582**	0.0211	0.186	0.1910
Voice & Accountability	-0.127	-0.5510**	-0.914**	0.2510
Political Stability	-0.095	-0.1320	-0.401	-0.2570
Regulatory Quality	0.497**	0.6160**	0.803***	0.7680**
Rule of Law	0.004	0.2510	0.251	-0.4550
Broad Money	0.146***	0.0155**	0.013*	0.0070
Constants			0.061	-0.9710
F-Statistic (First Stage)			10.37	12.10

Note: *** significant at 1%, ** significant at 5% , * significant at 10%

The results from the preferred Two Step System GMM specification for both manufacturing value added and industry value added are presented in Table 5. This estimator explicitly addresses the dynamic nature of industrial value added by including its lag and using internal instruments to mitigate endogeneity concerns. The coefficient on lagged industrial value added (0.173) is negative but statistically insignificant,

suggesting limited persistence. Political terror exhibits a negative but statistically insignificant association (-0.207). The negative coefficient aligns with theoretical expectations that higher political instability reduces industrial value added, though the relationship is not statistically significant in this model. In contrast, GDP growth demonstrates a positive and highly statistically significant effect of 0.145, indicating that industrial value added is procyclical. The model diagnostics support its validity: the Hansen test of overidentifying restrictions (p=0.442) fails to reject the null of instrument validity, and the Arellano-Bond test finds no evidence of second-order serial correlation in the first-differenced errors (AR(2), p=0.227). These results highlight the primacy of economic growth over political terror as a determinant of industrial performance in the sampled countries.

Table 4. Results of AR Test

Test	Statistic	p-value	95% Confidence Set
Anderson-Rubin (AR)	$\chi^2(1) = 1.61$	0.2045	[-1.64036, 0.45623]

Note: P = 20.45% shows insignificance

The analysis reveals a consistent narrative for the manufacturing sector. The coefficient on Political Terror for manufacturing value-added is negative and insignificant -0.359, mirroring the null finding for the broader industrial sector. This reinforces that state-sanctioned violence does not exhibit a statistically detectable causal impact on the core transformative activity of manufacturing. The expanded model specification further clarifies the binding constraints. Gross capital formation shows an even stronger positive and significant association with manufacturing (0.0376) than with total industry, underscoring the capital-intensive nature of the sector. Institutional variables demonstrate distinct sectoral relevance: while Regulatory Quality is a significant positive driver for both sectors, Rule of Law shows a strong, significant coefficient of 0.151 specifically for manufacturing. This demonstrates that for factory production, which relies heavily on enforceable contracts and secure property rights, the predictability of the legal framework is a more salient institutional factor than the level of political terror. The model diagnostics confirm its robustness, with no evidence of second-order serial correlation (p-value of 0.219) and valid instruments, lending further credibility to these sector-specific insights.

Our null finding invites comparison with recent reputable studies. Fotio and Karim (2024) report that political risk reduces industrialization in Africa using panel methods, while acknowledging unresolved endogeneity concerns. Berman et al. (2017) demonstrate that mineral wealth fuels local conflicts but also find that industrial enclaves often remain insulated from violence due to strategic elite protection. More recently, Boumbouya and Ocran (2025) show that commodity-based industrialization in Africa is more constrained by global market conditions than by domestic political factors. Our study contributes to this evolving literature by offering a causal estimate using an external instrumental variable,

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constitutionally fixed executive elections, which allows us to test whether state-sanctioned violence directly causes industrial stagnation or whether prior correlations reflect reverse causality. The null result we obtain suggests that, unlike Fotio and Karim (2024), once endogeneity is addressed, the causal effect of political terror on industrial growth is not statistically detectable in our sample.

Table 5. GMM Results for Industry VA & Manufacturing VA

	Industry VA	Manufacturing VA
Lag Industry VA	-0.173000	
Lag Manufacturing VA		-0.1374133
Political Terror	-0.207000	-0.359000
GDP growth (annual %)	0.145000***	0.191000***
Gross capital formation	0.025000***	0. 037600***
Export	0.020100***	0.011300***
Imports	-0.01200***	-0.01700***
Regulatory Quality	0.78600**	0.786000***
Rule of Law	0.251000***	0.151000***
Broad Money	0.128000**	0.235000***
Observations	266	266
Year Fixed Effects	Yes	Yes
Estimator	System GMM	System GMM
Observations	266	266
Countries	27	27
Instruments	30	30
AR(1) p-value	0.0620	0.0510
AR(2) p-value	0.227	0.219

Note: *** significant at 1%, ** significant at 5% , * significant at 10%

Our robust null finding that state political risk shows no statistically significant causal effect on industrial growth invites a contextualized interpretation within the distinct institutional and economic landscape of Sub-Saharan Africa. The results suggest that a national-level measure of state-sanctioned violence, while theoretically disruptive, may be a poor proxy for the de facto institutional environment governing industrial firms. This is underscored by our models, which show that specific governance dimensions, such as Regulatory Quality and Rule of Law, emerge as significant positive drivers. This pattern aligns with the concept of hybrid governance, in which firms often rely more on stable informal networks and adaptive arrangements than on fragile formal state structures to secure contracts and resolve disputes (Manara & Pani, 2023; Waiganjo & Odote, 2025).

Such systems can effectively buffer day-to-day business operations from the macro-political volatility captured by the PTS.

A pronounced spatial disconnect between the geography of violence and the location of industry compounds this institutional buffer. Industrial assets and manufacturing value-added are predominantly concentrated in major urban centers and capital regions (Acemoglu et al., 2022). In contrast, significant political violence often manifests in peripheral or rural areas (Tadesse, 2023). Consequently, national-level indices of political terror may not accurately reflect the localized security conditions in which the bulk of industrial capital is physically located. Aggregate industrial performance can therefore remain stable even amid heightened national-level political risk, as core productive zones are geographically insulated from direct violence, a factor our aggregate analysis cannot capture but which likely attenuates the observed statistical relationship.

In addition, the structure of African industry suggests that political risk may not be the primary binding constraint. The manufacturing sector in our sample is characterized by small-scale enterprises facing chronic structural deficits. Firm-level evidence consistently identifies infrastructure unreliability and access to finance as the most critical operational challenges, often ranking above political instability in enterprise surveys (OECD, 2025). The most immediate barriers to investment within the growth diagnostics framework, such as daily power outages or constrained credit, are likely more binding. Thus, marginal variations in measured state political risk may have a negligible effect on aggregate industrial output already held back by these more fundamental economic and infrastructural bottlenecks.

The macroeconomic context of our sample period (2000–2023) further complicates the relationship. This era included a commodity boom, in which strong GDP growth in many countries coincided with a declining share of manufacturing in GDP, a pattern termed premature deindustrialization (Rowthorn & Rowthorn, 2024). In economies where a significant portion of industrial output stems from capital-intensive extractive enclaves, the transmission mechanism from domestic political instability to industrial performance weakens. These enclaves, often secured by private or state-protected arrangements, can operate semi-autonomously from broader domestic political currents. As a result, industrial fortunes may be more closely tied to global commodity prices and foreign investment than to domestic political conditions, thereby diluting the measurable impact of internal political terror at the national level.

A compelling political-economy explanation for this decoupling is the strategic selectivity of state violence, aligned with the regime-survival logic. Political elites may actively insulate industrial and revenue-generating zones from the state-sanctioned violence used to consolidate power elsewhere. As Wiebusch & Aniekwe (2019) note, African ruling coalitions often maintain power through a dual strategy of coercion and co-optation, which requires safeguarding the economic bases that fund patronage and state security. Industrial enclaves, particularly in extractive sectors, represent critical nodes in this political settlement (Li et al., 2023; Sablin, 2022). Regimes thus have a vested interest in

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creating *de facto* security and institutional firewalls around these zones, ensuring production continues uninterrupted even as repression targets political opponents in other regions (Fambeu, 2024). This deliberate compartmentalization means national-level measures of political terror may systematically fail to reflect the protected operational environment of key industrial assets.

At length, the null result may reflect differences in sensitivity among capital sources. Foreign direct investment (FDI) is typically more sensitive to formal country risk ratings and perceptions of instability (Osuma et al., 2024). In contrast, domestic investors, embedded in local networks and possessing adaptive informal strategies, may be more resilient or even opportunistic during periods of volatility (Wiebusch & Aniekwe, 2019; Williams, 2021). If contractions in sensitive FDI are offset by resilient or compensatory domestic investment, aggregate industrial output, the focus of this study, could remain stable. This potential substitution effect suggests that political terror might reallocate capital within the industrial sector without necessarily reducing total output, a mechanism that aggregate national-level data cannot capture. Collectively, these context-specific factors, such as hybrid governance, spatial mismatch, binding structural constraints, the enclave nature of industry, strategic elite protection, and capital source heterogeneity, provide a multifaceted explanation for why the conventional theoretical expectation of a strong negative effect is not borne out in our empirical analysis of contemporary Sub-Saharan Africa.

CONCLUSION

This study empirically tested the hypothesis, derived from dominant institutional and microeconomic theory, that state-sanctioned political violence has a significant negative causal effect on industrial growth in Sub-Saharan Africa. Our analysis of 30 countries from 2000–2023, employing a novel instrumental-variable strategy that exploits constitutionally fixed elections, yields a robust null finding. This result persists across multiple estimators (2SLS, LIML, and System GMM) and is validated by weak-instrument-robust inference. The divergence from conventional OLS correlations suggests that earlier observed negative associations likely reflect endogeneity, such as reverse causality, rather than a genuine causal impact of violence on industrial performance. Thus, for our sample and period, state political risk, as measured by the Political Terror Scale, does not constitute a statistically discernible binding constraint on aggregate industrial value-added growth.

The policy implications of this finding are significant for industrial strategy in moderately unstable African contexts. Rather than prioritizing broad political risk mitigation as a precondition for industrial policy, policymakers should target four immediate, binding constraints identified by our models: sustaining GDP growth, boosting physical capital formation, improving regulatory quality through business registration and contract enforcement, and deepening financial systems to expand credit access. These four drivers show consistently significant effects on industrial growth, whereas political terror

does not. This is not to dismiss the importance of peace and security in extreme conflict zones. However, in settings of measured instability, a focused approach on proximate economic and regulatory drivers may yield more effective industrial outcomes than an overemphasis on headline political risk indicators.

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Economic Agglomeration and District-Level Carbon Emissions in Indonesia

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ABSTRACT

Research Originality: This study contributes to the literature by incorporating employment density as a proxy of economic agglomeration into an extended STIRPAT framework to examine its nonlinear relationship with district-level carbon emissions in Indonesia.

Research Objectives: This study aims to investigate whether economic agglomeration promotes emission efficiency or intensifies environmental pressure, and to identify potential nonlinear dynamics across Indonesian districts.

Research Methods: This study employs a balanced panel dataset of 514 districts and municipalities in Indonesia over the period 2017–2024. A two-way fixed-effects model is estimated within an extended STIRPAT framework, with a quadratic specification to capture nonlinear effects.

Empirical Results: The results indicate that economic agglomeration is associated with lower carbon emissions per capita, suggesting efficiency effects. However, the nonlinear estimation reveals a U-shaped relationship: agglomeration reduces emissions at lower levels but increases environmental pressure beyond a threshold. The findings also indicate substantial regional heterogeneity.

Implications: The results suggest that agglomeration does not inherently lead to environmental improvements. Differentiated policies should strengthen regional growth and efficiency in low-density areas while prioritizing low-carbon transitions and congestion mitigation in dense regions.

Keywords:
economic agglomeration; employment density; carbon emissions; spatial concentration; nonlinear relationship

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INTRODUCTION

Indonesia has experienced rapid urbanization and spatial concentration of economic activities over the past decade (Jamal, 2017; Wilonoyudho et al., 2017). The growing density of labor and production in urban districts has been widely associated with productivity gains, knowledge spillovers, and structural transformation (Cottineau et al., 2019). Economic agglomeration theory suggests that spatial concentration enhances efficiency through sharing of infrastructure, improved labor matching, and accelerated learning and technological diffusion (Li & Li, 2018; McCann & van Oort, 2019). Dense regions may utilize transport networks, energy systems, and public services more efficiently, potentially reducing emissions per unit of output (Fatorachian & Kazemi, 2025). However, agglomeration may simultaneously intensify environmental pressure through scale effects, rising energy demand, congestion, and industrial expansion. From a theoretical perspective, agglomeration may reduce carbon emissions through efficiency improvements, technological diffusion, and better infrastructure utilization (Resbeut et al., 2019). Dense economic areas can lower transportation costs, enhance public service provision, and promote energy efficiency. Conversely, spatial concentration may intensify emissions due to scale effects, higher energy demand, and congestion externalities (Zhou et al., 2024). The net environmental impact therefore depends on the balance between efficiency and scale dynamics.

The theoretical linkage between employment density and environmental outcomes draws on the micro-foundations of agglomeration proposed by Gilles Duranton and Diego Puga (2004), which identify three channels: sharing, matching, and learning. Through sharing, dense economic areas can operate infrastructure (such as transport systems, energy networks, and waste facilities) more efficiently, potentially lowering energy intensity per unit of output (Gatzioura et al., 2019). Through matching, thicker labor markets improve the allocation of skills, including green and energy-efficiency expertise, thereby reducing production inefficiencies (Yi et al., 2021). Through learning, spatial proximity accelerates knowledge spillovers and the diffusion of cleaner technologies (Wang et al., 2020; Yu et al., 2022). These mechanisms suggest that agglomeration may generate environmental efficiency effects. However, in contexts characterized by fossil-fuel dependence and energy-intensive production structures, scale effects may dominate these channels (Ahmad et al., 2021), making the environmental impact of agglomeration an empirical question.

Empirical evidence on the relationship between economic agglomeration and carbon emissions remains mixed and geographically concentrated. A substantial portion of the literature is based on Chinese regional data. Research in China often highlights the emission-reducing effects of density, the triggering of innovation, and the acceleration of the adoption of environmentally friendly technologies (Hong et al., 2019). On the other hand, findings in developing contexts tend to emphasize the dominance of production scale and fossil-fuel dependence (Cheng, 2016; Han et al., 2018). These findings suggest nonlinear, context-dependent dynamics in which structural conditions, energy composition, and industrial upgrading determine whether agglomeration contributes to environmental improvement (Liu et al., 2024).

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Beyond China, evidence from other countries further underscores the structural sensitivity of the agglomeration–emissions nexus. Using regional manufacturing data from South Korea, Wu et al. (2025) show that specialized industrial agglomeration tends to increase carbon emissions, whereas diversified agglomeration may reduce environmental pressure. This distinction highlights that the environmental consequences of spatial concentration depend not merely on density, but on the composition and maturity of regional economic structures. Studies in Sub-Saharan Africa, for example, indicate that economic transformation does not automatically translate into environmental improvement. Nkengfack et al. (2019) show that in many low- and middle-income countries, the scale effect remains the principal driver of rising emissions, while limited technological adoption and weak regulatory enforcement constrain the emergence of technical efficiency gains.

Despite the growing literature on agglomeration and environmental outcomes, several important gaps remain. First, existing studies are largely focused at the cross-country or provincial levels, with limited evidence at finer spatial scales in large, lower-middle-income economies. Most existing studies rely on cross-country, provincial, or metropolitan aggregates, leaving district-level dynamics underexplored, despite substantial regional disparities. In the Indonesian context, studies commonly focus on economic growth, urbanization, or energy consumption, yet rarely explicitly incorporate economic agglomeration (particularly measured by employment density) as a core explanatory variable (Kurniawan & Managi, 2018). As a result, the role of spatial economic concentration in shaping environmental outcomes remains insufficiently understood. Second, the potential nonlinear relationship between agglomeration and emissions has not been systematically examined at the subnational level in developing countries, where structural conditions differ markedly from advanced economies. Given Indonesia's substantial regional disparities and heterogeneous development patterns, understanding how agglomeration interacts with carbon emissions at the subnational level is crucial. Third, although the STIRPAT framework is widely used to analyze environmental pressures (Cooray & Özmen, 2024; Yilmaz & Sensoy, 2022), spatial economic density is rarely incorporated explicitly as a core explanatory variable (Aziz & Chowdhury, 2023; Borsha et al., 2024). Population and income are commonly included, yet the distinct role of employment density as a measure of economic concentration is seldom examined within this framework. Fourth, developing economies characterized by substantial regional disparities and fossil-fuel dependence may exhibit agglomeration dynamics that differ fundamentally from those observed in more advanced contexts.

Indonesia provides a particularly relevant setting to address these gaps. As a large, lower-middle-income country with pronounced interregional disparities, a heterogeneous industrial structure, and continued reliance on fossil fuels, Indonesia offers an opportunity to assess whether agglomeration generates environmental efficiency gains or reinforces scale-driven emission pressures. District-level analysis is especially important given the country's administrative fragmentation and uneven development trajectories.

This study addresses these gaps and contributes to the literature in three main ways. First, it provides district-level evidence from 514 districts and municipalities in

Indonesia over the period 2017–2024, offering one of the most comprehensive subnational analyses of agglomeration and carbon emissions in a developing economy. Second, it explicitly embeds employment density into an extended STIRPAT framework (York et al., 2003), integrating spatial economic concentration into a well-established environmental impact model. Third, the study examines potential nonlinear dynamics by incorporating a quadratic specification of agglomeration, thereby extending the Environmental Kuznets Curve (EKC) perspective beyond income toward spatial economic intensity (Chanda et al., 2024). Accordingly, this study aims to examine the relationship between economic agglomeration and district-level carbon emissions in Indonesia, with particular emphasis on identifying whether spatial concentration promotes emission efficiency or intensifies environmental pressure. It further evaluates nonlinear patterns and regional heterogeneity to clarify the conditions under which agglomeration may support or hinder sustainable development.

METHODS

This study employs secondary district-level panel data covering 514 districts and municipalities in Indonesia over the period 2017–2024. The observation window is selected for two main considerations. First, it captures an important phase in Indonesia's climate policy trajectory, including the implementation of Nationally Determined Contributions (NDCs) and the strengthening of green economy initiatives in the post-pandemic period. This timeframe provides a meaningful basis for assessing whether increasing economic agglomeration is associated with improvements in carbon efficiency (technique effects) or remains driven by scale-related emission pressures. Second, the selected period ensures a high degree of data consistency and comparability across districts. While some variables are available for earlier years, the coverage and harmonization of key indicators become more stable in the more recent period. Focusing on 2017–2024, therefore, allows the analysis to rely on a consistent, well-aligned dataset, thereby enhancing the robustness and reliability of the empirical results.

The data were obtained from various sources. Carbon emission data are obtained from the Emissions Database for Global Atmospheric Research (EDGAR), while socioeconomic indicators are compiled from national statistical and investment databases. The balanced panel consists of 4,112 observations. The data sourced from these institutions are predominant due to their broad global coverage (satellite data) and consistent availability across years. Table 1 presents the more detailed information about the operational variables.

As for the variables used in this study, the dependent variable is carbon emissions per capita, measured in metric tons of CO_2 per capita (Chanda et al., 2024), defined as CO_2 emissions per capita per year at the district level. For the independent variables, economic agglomeration is proxied by employment density, measured as the number of workers per square kilometer (Ercole & O'Neill, 2017; Melo et al., 2009). In the modern literature on economic agglomeration, Combes and Gobillon (2021) contend that economic density is a more canonical and superior measure than total population

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mass for capturing agglomeration effects, as it better reflects the intensity of interactions among economic agents within a given region. Following previous studies, other variables used to control for the carbon emission variable are economic growth, proxied by Gross Regional Domestic Product (GRDP) per capita at constant prices, share of manufacture industry to GDP, share of tertiary industry to GDP, and ratio of foreign direct investment to GDP (Yi et al., 2021; Yu et al., 2022; Zhou et al., 2024). This study covers data from 2017–2024, as consistent district-level socioeconomic indicators across Indonesia have been widely available only since 2017. Although EDGAR provides emission estimates for earlier years, several explanatory variables used in this study are not consistently reported at the district level before 2017.

Table 1. Definition of variables, frequency and sources

Variables	Definitions	Measurements	Sources	References
Carbon Dioxide Emission Per Capita	CO_2 emissions per capita (metric tons of CO_2 per person per year) at the district level	Metric tons of CO_2 per capita	EDGAR	(Chanda et al., 2024; Crippa et al., 2025)
Economic Agglomeration	Employment density, measured as total number of employed workers per square kilometer	total number of employed workers/km^2	BPS	(Ercole & O'neill, 2017; Melo et al., 2009)
Gross Domestic Product Per Capita	Gross regional domestic product per capita at constant prices	IDR per capita	BPS	(Yi et al., 2021; Yu et al., 2022; Zhou et al., 2024)
Share of Manufacture Industry to GDP	Share of manufacturing value added in total regional GDP (percent)	Total regional GDP in Manufacture Industry/GDP	BPS	(Yi et al., 2021; Yu et al., 2022; Zhou et al., 2024)
Share of Tertiary Industry to GDP	Share of tertiary sector value added in total regional GDP (percent)	Total regional GDP in Tertiary Industry/GDP	BPS	(Yi et al., 2021; Yu et al., 2022; Zhou et al., 2024)
Ratio of Foreign Direct Investment to GDP	Ratio of foreign direct investment in total regional GDP (percent)	Total regional FDI/GDP	BKPM / Ministry of Investment	(Yi et al., 2021; Yu et al., 2022; Zhou et al., 2024)

Given the coverage of 514 districts and municipalities in Indonesia, which is characterized by substantial geographic diversity, heterogeneous development trajectories, and varying ecological conditions (Glaeser & Kahn, 2008), estimating the model using pooled Ordinary Least Squares (OLS) may yield biased results due to omitted variable bias. To address unobserved heterogeneity, this study employs a Two-Way Fixed Effects (TWFE) specification, formulated as follows:

$$ln(emission_{it}) = \beta_1 ln(agglo_{it}) + \beta_n lnX_{nit} + \alpha_i + \delta_t + \varepsilon_{it} \quad (1)$$

Although the two-way fixed-effects specification helps mitigate omitted variable bias by controlling for time-invariant district characteristics and common time shocks, potential endogeneity concerns may persist. In particular, reverse causality between emissions and

economic agglomeration, as well as possible measurement errors in district-level emission estimates, cannot be entirely ruled out. Therefore, the estimated coefficients should be interpreted as conditional associations rather than strictly causal effects.

To examine the relationship between economic agglomeration and carbon emissions, this study adopts an extended STIRPAT framework. Carbon emissions are modeled as a function of population size, income per capita, and structural factors. Employment density is incorporated as an additional explanatory variable to capture the spatial concentration of economic activity. This extension allows the model to distinguish between population scale effects and spatial interaction intensity, thereby enriching the conventional STIRPAT specification (Yi et al., 2021; Yu et al., 2022; Zhou et al., 2024).

Real income per capita is essential for testing the EKC hypothesis at the district and municipal levels, while ensuring that the estimated impact of agglomeration on carbon emissions is identified net of income effects. The use of constant-price GRDP is theoretically justified, as carbon emissions are more closely linked to physical output and energy consumption than to nominal price fluctuations. Following the EKC tradition, this study further incorporates a nonlinear specification of employment density ($agglo^2$) to examine whether agglomeration exhibits an inverted-U or U-shaped relationship with emissions. Consistent with the EKC literature (Shahbaz et al., 2013; Stern, 2017), the nonlinear framework allows for the possibility that environmental pressure initially rises with increasing economic intensity but declines after a certain threshold due to efficiency gains, structural transformation, and technological upgrading. In this context, the EKC concept is extended from an income–environment relationship to an agglomeration–environment relationship, where employment density captures the spatial concentration of economic activity and the identified nonlinear pattern reflects the balance between scale effects and spatial efficiency gains. With that, the model for nonlinear specification to address the EKC concept, is formulated as follows:

$$ln(emission_{it}) = \beta_1 ln(agglo_{it}) + \beta_2 ln(agglo^2{}_{it}) + \beta_n lnX_{nit} + \alpha_i + \delta_t + \varepsilon_{it} \quad (2)$$

All variables are transformed into natural logarithms to interpret coefficients as elasticities and to reduce heteroskedasticity. Accordingly, the estimated coefficients represent elasticities, indicating the percentage change in carbon emissions associated with a one percent change in each explanatory variable, holding other factors constant. To examine potential nonlinear dynamics in the agglomeration–emissions relationship, an alternative specification includes a quadratic term for economic agglomeration. This specification allows the analysis to assess whether increasing employment density generates diminishing environmental efficiency or reversals beyond certain density levels (Koirala et al., 2025).

To further explore regional heterogeneity, subsample estimates are conducted by dividing districts into geographic and administrative categories. First, districts are grouped into those located in Java and those outside Java, reflecting Indonesia's well-documented spatial concentration of economic activities and infrastructure in Java relative to other regions (Yunitasari et al., 2023). Second, districts are categorized by administrative classification as regencies or cities, which differ substantially in urbanization levels,

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economic structures, and population densities (Falahuddin et al., 2024). This approach allows the analysis to examine whether the agglomeration–emissions relationship varies across regions with different spatial and institutional characteristics.

The summary statistics of the variables used in this study are presented in Table 2. The average carbon emissions per capita at the district and municipal level (emission) amount to 0.471 tons per person, accompanied by a relatively large standard deviation (2.756). This pattern reflects substantial disparities in environmental pressure across regions in Indonesia. The highest emission levels are generally concentrated in areas with intensive heavy industrial activities or large-scale extractive industries, such as Bontang and Cilegon. Conversely, extremely low emission levels are observed in remote inland districts, mainly at the eastern part of Indonesia, where economic activities remain relatively limited compared with the geographic size of the administrative area.

Table 2. Summary Statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
Carbon emission (emission)	4112	0.471	2.756	0.000043	49.917
Economic agglomeration (agglo)	4112	5276.153	1244.837	0.340	10754.610
Economic prosperity (gdpcap)	4112	38.662	44.868	3.969	570.117
Manufacture share (manugdp)	4112	12.766	14.538	0	83.869
Tertiary share (tertgdp)	4112	43.599	17.371	2.628	90.902
FDI-to-GDP (fdigdp)	4112	9.206	28.277	0	1040.252

Economic agglomeration (agglo) exhibits a mean value of 5,276 workers per square kilometer, with a very wide range from 0.34 to 10,754 workers per km². This pattern highlights a pronounced spatial polarization between major economic centers, particularly metropolitan areas in Java, and sparsely populated non-urban regions. The use of employment density as a proxy for agglomeration is consistent with the framework proposed by Duranton & Puga (2004), as variations in labor density are expected to capture mechanisms of sharing and learning that may influence regional energy efficiency and emission levels.

From an economic prosperity perspective, the average real GRDP per capita (gdpcap) across districts is approximately 38.66 million rupiah per person. Employing constant prices is methodologically essential because it removes the influence of inflation, allowing the observed variations in income levels to more accurately represent real changes in economic output that are more closely associated with energy use and carbon emissions. Consequently, this indicator provides a reliable foundation for assessing the validity of the Environmental Kuznets Curve (EKC) hypothesis within the Indonesian context. In terms of economic structure, subnational economies in Indonesia are largely dominated by the service or tertiary sector, which contributes on average 43.59 percent to regional GDP (tertgdp), substantially higher than the manufacturing sector, whose average share

is only 12.76 percent (manugdp). Despite this general pattern, Indonesia's regional economies remain highly heterogeneous, with certain districts exhibiting strong industrial specialization. For instance, manufacturing activities remain relatively prominent in areas such as Kediri City and Kudus Regency, reflecting localized industrial concentration within an otherwise service-oriented national structure. The predominance of the service sector is also consistent with the phenomenon of premature deindustrialization described in the literature, where structural transformation toward services occurs before manufacturing reaches levels typical of advanced economies, potentially generating emission dynamics that differ from those commonly observed in developed countries. Finally, the ratio of foreign direct investment to regional GDP (fdigdp) averages 9.206 percent, although its distribution is highly uneven, with maximum values that exceed local GDP by several multiples. These extreme observations indicate the presence of regions that receive disproportionately large inflows of foreign investment relative to their local economies, particularly in districts hosting large-scale mining operations or strategic resource-based projects, such as Central Halmahera in early 2018 and North Maluku from early 2015 to late 2019.

RESULTS AND DISCUSSION

The empirical results reveal three main findings regarding the relationship between economic agglomeration and district-level carbon emissions in Indonesia. First, economic agglomeration, proxied by employment density, is negatively associated with per capita carbon emissions, suggesting efficiency effects arising from spatial concentration. Second, the nonlinear specification indicates a U-shaped relationship, where agglomeration initially reduces emissions but eventually increases environmental pressure beyond a certain threshold. Third, the heterogeneity analysis shows that these effects vary across regions and administrative structures, with more robust emission-reducing effects observed in non-Java regions and regencies. These findings highlight that the environmental consequences of agglomeration are not uniform but depend on the level of economic density and the characteristics of regional development.

The estimation results are presented in Table 3. Following the STIRPAT framework, the empirical specification relates environmental pressure, measured by district-level per capita carbon emissions, to economic activity, structural factors, and spatial agglomeration. All regressions, formulated in Equations (1) and (2), are estimated using a fixed-effects panel model with year dummies to control for time-specific shocks affecting all districts. To address potential heteroskedasticity and serial correlation within districts, standard errors are clustered at the district level.

The baseline estimation results in Table 3 indicate that economic agglomeration is negatively associated with district-level per capita carbon emissions. The estimated elasticity suggests that a 1% increase in employment density is associated with a modest 0.11% reduction in emissions. The negative association between employment density and per capita carbon emissions suggests that agglomeration may generate environmental efficiency gains through several channels. In line with the micro-foundations of agglomeration economies,

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higher density facilitates more efficient use of infrastructure, including transport networks and energy systems, thereby reducing energy intensity per unit of output. These findings support the presence of an efficiency effect, whereby spatial concentration improves infrastructure utilization and energy efficiency (Yi et al., 2021). Consistent with the STIRPAT framework, income per capita and energy use exhibit positive and statistically significant effects on emissions, reflecting the dominance of scale effects in driving environmental pressure (Zhou et al., 2024). In addition, denser labor markets improve the matching of skills, potentially enhancing the adoption of energy-efficient technologies and production practices. These mechanisms are consistent with recent empirical findings that highlight the role of urban density in improving energy efficiency and reducing carbon intensity in developing economies. However, the relatively small magnitude of the coefficient indicates that these efficiency gains remain limited and may not fully offset the scale effects associated with economic expansion and rising energy demand.

Table 3. The Results of OLS and Nonlinear Estimations

	TWFE ln(emission)	Nonlinear ln(emission)
ln(agglo)	-0.113*** (0.0324)	-0.343*** (0.0890)
ln(agglo^2)		0.0358*** (0.0119)
ln(gdpcap)	0.684*** (0.0475)	0.663*** (0.178)
ln(manugdp)	-0.00387 (0.0264)	-0.00443 (0.0347)
ln(tertgdp)	0.566*** (0.0677)	0.532*** (0.189)
ln(fdigdp)	-0.00973*** (0.00253)	-0.00975** (0.00435)
Constant	-7.109*** (0.421)	-6.74040*** (1.27589)
F-Statistic	27.63	26.72
R-Square (within)	0.167	0.171
rho	0.99324256	0.99252737

Note: *** significant at 1%, ** significant at 5%, * significant at 10%

This finding is broadly consistent with recent studies in developing economies, which document that moderate levels of economic density can contribute to lower emissions through efficiency improvements. For example, studies using regional data in China find that urban density is associated with reduced carbon intensity due to better infrastructure utilization and technological diffusion (Yu et al., 2022). However, the relatively modest effect observed in Indonesia suggests that structural factors, such as continued reliance on fossil fuels and limited technological upgrading, may constrain the extent to which agglomeration translates into environmental benefits. This contrasts with more advanced

urban systems, where stronger institutional capacity and cleaner energy transitions tend to amplify the environmental advantages of spatial concentration (F. Wang et al., 2020).

Moreover, the estimation results with a quadratic specification of employment density ($agglo^2$) reveal a non-linear relationship between agglomeration and per capita carbon emissions. Employment density enters negatively and significantly, while its squared term is positive and significant, indicating a U-shaped pattern. At low to moderate densities, increased agglomeration is associated with lower per capita emissions, suggesting efficiency effects. However, beyond a certain density threshold, further agglomeration correlates with rising emissions (Shahbaz et al., 2013; Stern, 2017). Additionally, in quadratic environmental models, calculating the turning point is a standard procedure for identifying the explanatory variable level at which the marginal effect changes sign, allowing researchers to determine the threshold at which environmental improvements begin to reverse (Stern, 2004). The turning point is obtained by setting the first derivative of the estimated quadratic function equal to zero.

Formally, the turning point of a quadratic specification can be derived as follows:

$$\mathrm{TP} = -\frac{\beta_1}{2\beta_2} \tag{3}$$

where β_1 represents the coefficient of employment density, and β_2 represents the coefficient of its squared term. Applying this formulation to the estimated coefficients (converted back from the natural-log form) yields a turning point of approximately 120 workers per km^2, indicating the density level at which the marginal effect of agglomeration on emissions shifts from negative to positive. This suggests that, up to this threshold, the benefits of spatial concentration (such as shared infrastructure, shorter commuting distances, and more efficient use of production inputs) may help reduce per capita emissions. Once employment density exceeds this level, however, additional agglomeration tends to intensify emission pressures (Tatoğlu & Polat, 2021).

These findings suggest that agglomeration-related efficiency effects, such as shared infrastructure use and the consolidation of economic activity, operate primarily at the early stages of increasing employment density. However, at very high levels of agglomeration, such efficiency gains appear to be offset by intensified economic and energy pressures, including transport congestion, production expansion, and the continued dominance of energy-intensive sectors (X. Wang et al., 2022). Importantly, this nonlinear pattern should not be interpreted as causal evidence of an Environmental Kuznets Curve within the agglomeration context. Rather, it is more appropriately understood as an empirical relationship that reflects the dynamic balance between efficiency and scale effects, without implying the existence of a causal optimal turning point.

The identified U-shaped relationship further suggests that the environmental impact of agglomeration is highly dependent on the stage of economic density. At lower levels of agglomeration, efficiency effects dominate, as firms and households benefit from shared infrastructure, shorter commuting distances, and improved coordination of economic activities. However, as density increases beyond a certain threshold, scale effects begin to outweigh these efficiency gains. In highly concentrated areas, rising energy demand,

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transport congestion, and the expansion of energy-intensive activities may lead to increased emissions. This pattern is particularly relevant in the Indonesian context, where rapid urbanization is not always accompanied by proportional improvements in clean energy infrastructure or environmental regulation. Therefore, the impact of this cannot be assumed to be linear, uniform, or consistent across regions; it may even vary across economic sectors depending on energy intensity and the dominant technologies in each sector (Han et al., 2018). As a result, excessive agglomeration may exacerbate environmental pressure rather than alleviate it (Zhou et al., 2024).

Subsample estimations further reveal substantial regional heterogeneity in the agglomeration–emissions relationship, as presented in Table 4. The estimation results show that economic agglomeration is negatively associated with per capita carbon emissions in both Java and non-Java regions. In Java, the coefficient is –0.208 and statistically significant at the 10 percent level, indicating a relatively larger emission-reducing effect but with lower statistical precision. Outside Java, the coefficient is smaller (–0.095) yet significant at the 1 percent level, suggesting a more stable and statistically robust relationship. Although the magnitude varies across regions, the consistent negative sign indicates that higher employment density is associated with lower per capita emissions. This pattern is broadly consistent with the urban economics literature, which emphasizes that agglomeration economies, arising from mechanisms such as shared infrastructure, labor market matching, and knowledge spillovers, can enhance production efficiency and reduce energy intensity at moderate levels of spatial concentration (Duranton & Puga, 2004).

Table 4. The Results of Heterogeneity Analysis

	Java ln(emission)	Outside Java ln(emission)	City ln(emission)	District ln(emission)
ln(agglo)	-0.208* (0.118)	-0.0953*** (0.0346)	-0.161 (0.117)	-0.100*** (0.0344)
ln(gdpcap)	0.632*** (0.172)	0.649*** (0.0512)	1.006*** (0.142)	0.623*** (0.0517)
ln(manugdp)	0.115 (0.125)	-0.0223 (0.0282)	0.0205 (0.115)	0.0150 (0.0279)
ln(tertgdp)	0.356 (0.237)	0.498*** (0.0731)	0.420 (0.257)	0.545*** (0.0717)
ln(fdigdp)	0.00685 (0.00565)	-0.0120*** (0.00283)	-0.00469 (0.00527)	-0.0114*** (0.00287)
Constant	-4.403*** (1.645)	-7.211*** (0.439)	-5.100*** (1.724)	-7.483*** (0.427)
F-Statistic	4.92	58.35	8.87	53.09
R-Square (within)	0.0699	0.2007	0.1352	0.1805
rho	0.98675542	0.99309905	0.98945552	0.9912444

Note: *** significant at 1%, ** significant at 5%, * significant at 10%

The stronger statistical significance observed outside Java may reflect differences in the stage of urban and economic development across Indonesian regions. Java hosts the country's most mature metropolitan systems, characterized by highly complex industrial structures, extensive transportation networks, and dense economic interactions (Duranton & Puga, 2004). In such environments, the environmental impacts of agglomeration may be influenced by multiple competing forces, including congestion effects, industrial clustering, and spatial spillovers across neighboring jurisdictions (Duranton & Turner, 2011; Wang et al., 2020). These factors can introduce additional variability in emissions outcomes and reduce statistical precision. In contrast, many districts outside Java are still undergoing earlier stages of urbanization and structural transformation. In these contexts, incremental increases in employment density may more clearly reflect improvements in infrastructure utilization, production efficiency, and energy use, resulting in a more stable relationship between agglomeration and emissions (Henderson, 2003).

A similar pattern emerges when comparing cities and regencies. The agglomeration coefficient remains negative in both groups, implying that greater economic concentration tends to be associated with lower per capita emissions. In regencies, the estimated effect (–0.100) is statistically significant at the 1 percent level, whereas in cities, although the coefficient is larger in magnitude (–0.161), it is not statistically significant at conventional levels. This difference may be related to the structural heterogeneity of Indonesian cities, where variations in industrial composition, urban transport intensity, and population density can produce more complex emissions dynamics (Glaeser & Kahn, 2010; Wang et al., 2019). By contrast, regencies often exhibit lower baseline levels of agglomeration and relatively simpler economic structures, allowing the efficiency effects of spatial concentration to appear more consistently in empirical estimates (Henderson, 2003; Yu et al., 2022).

These findings in heterogeneity analysis are also consistent with the nonlinear agglomeration pattern identified in the baseline specification, suggesting that the environmental benefits of spatial concentration may diminish as urban density approaches higher levels. This result suggests that the environmental efficiency effects of agglomeration are more consistently observed in regions that are still experiencing relatively early stages of urban concentration. In such contexts, increasing employment density may improve infrastructure utilization, shorten commuting distances, and facilitate more efficient allocation of labor and capital. However, as agglomeration intensifies in highly urbanized environments, congestion externalities, expanded production scale, and rising energy demand may partially offset these efficiency gains. Similar heterogeneous patterns have been documented in recent empirical studies. For example, a city-level analysis of Chinese urban systems shows that the environmental effects of population agglomeration vary substantially across regions depending on industrial structure and technological capability, with denser cities often exhibiting lower carbon intensity due to improved industrial efficiency and technological upgrades (Yan & Huang, 2022). Likewise, research on urban agglomeration reforms in the Yangtze River Delta finds that carbon emission responses differ significantly between central and peripheral cities, highlighting the importance of

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spatial heterogeneity in understanding the environmental consequences of agglomeration (Jin & Chen, 2022). Additional evidence from spatial analyses of Chinese cities further indicates that drivers of carbon emissions exhibit strong regional variation associated with differences in economic structure, infrastructure development, and technological capacity (Guo & Yu, 2024). Taken together, these studies reinforce the interpretation that the environmental impacts of agglomeration are inherently context-dependent and may vary across regions with different stages of urbanization and economic development.

CONCLUSION

This study examines whether economic agglomeration promotes environmental efficiency or intensifies carbon emissions at the district level in Indonesia. The empirical results show that economic agglomeration, measured by employment density, is generally associated with lower per capita carbon emissions, indicating efficiency effects of spatial concentration. However, the nonlinear specification reveals that this relationship is not monotonic. At relatively low to moderate levels of agglomeration, increasing employment density reduces emissions, but beyond a certain threshold, further concentration increases emissions. These findings suggest that the environmental impact of agglomeration depends critically on the balance between efficiency gains and scale effects, and therefore does not inherently guarantee environmental improvement across all levels of economic density.

The results also indicate that the environmental effects of agglomeration vary across regions and administrative structures. The emission-reducing effect is more consistently observed in non-Java regions and in regencies, where economic concentration is still at an earlier stage. In contrast, in more developed and densely populated areas, the environmental benefits of agglomeration appear to weaken, likely due to increasing congestion, higher energy demand, and structural dependence on energy-intensive activities. These findings imply that policy strategies should adopt a differentiated and place-based approach. In regions with relatively low to moderate levels of agglomeration, policies should focus on strengthening regional growth centers, improving infrastructure connectivity, and facilitating the adoption of energy-efficient technologies to maximize efficiency gains. Meanwhile, in highly urbanized areas, policy priorities should shift toward mitigating congestion, promoting low-carbon transport systems, accelerating the transition to cleaner energy sources, and encouraging industrial upgrading toward less energy-intensive sectors. Such differentiated strategies are essential to ensure that economic agglomeration supports sustainable, low-carbon development rather than exacerbating environmental pressures.

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Sustainable Regional Economic Development through Cultural and Human Capital: Evidence from Indonesia

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ABSTRACT

Research Originality: This study offers novel insights by examining the mediating role of human capital in the relationship between cultural capital and regional economic development in Indonesia.

Research Objectives: This study aims to examine the effect of cultural capital on Regional economic development and to investigate the mediating role of human capital in the relationship between cultural capital and regional economic development.

Research Methods: This study employs panel data regression analysis using the Fixed Effects Model (FEM) and path analysis across 34 Indonesian provinces over the period 2019–2023.

Empirical Results: The findings indicate that cultural capital positively affects regional economic development. Cultural tourist attractions and intangible cultural heritage do not have a significant effect on regional economic development. Furthermore, human capital plays a significant moderating role in the relationship between cultural capital and regional economic development, suggesting that cultural capital contributes more effectively to regional development.

Implications: This study suggests that policymakers should continue to preserve and strengthen existing cultural capital across regions to improve access to public services and enhance living conditions. Ultimately, such an approach can support sustainable economic development.

Keywords:
cultural economics; human development; regional economic development; panel data models

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INTRODUCTION

To date, poverty remains a persistent challenge across nearly all countries worldwide, while efforts to improve societal welfare remain a central policy priority. In Indonesia, the poverty rate remains at approximately 8.25%, according to the Indonesian Central Statistics Agency. Consequently, countries around the world, including Indonesia, have committed to achieving the Sustainable Development Goals (SDGs) by 2030, with the eradication of poverty as a primary objective. Regional economic development is widely regarded as a critical driver in accelerating national economic growth, enhancing societal welfare, and reducing poverty (Paska et al., 2025; Song et al., 2022). Addressing challenges at the grassroots level is considered to have substantial potential to accelerate problem resolution at the national scale (Hu et al., 2022; Sarjiyanto et al., 2023). Regional economic development can be conceptualized as a process whereby local governments, in collaboration with communities and the private sector, strategically manage available resources to generate employment opportunities and promote sustained economic growth within a region (Widianingsih et al., 2023).

Cultural capital is increasingly recognized as a key driver of bottom-up development and economic growth. Cultural capital refers to a community's nonfinancial assets, including values, cultural heritage, beliefs, knowledge, norms, social networks, and institutional practices that shape economic behavior and productivity (Plaiphum & Tansuchat, 2023). Beyond its symbolic meaning, cultural capital functions as a strategic asset that can influence economic outcomes through investment, consumption, and innovation (Kafka & Kostis, 2021). According to Bourdieu (2018), cultural capital is a form of non-economic asset, alongside economic and social capital, that influences individuals' access to opportunities such as education, employment, and social mobility. Within the broader framework of social reproduction theory, cultural capital explains that social inequality arises not only from economic disparities but also from unequal access to values, knowledge, skills, and culturally recognized credentials, thereby contributing to the persistence of advantages and disadvantages across generations (Goulding, 2008). Cultural capital developed within the family context enhances an individual's capacity to acquire and mobilize cultural resources that support personal and social advancement. It can be categorized into three forms: embodied cultural capital, which encompasses values, skills, and cultural participation; objectified cultural capital, referring to tangible assets such as books and tools; and institutionalized cultural capital, reflected in formal qualifications, including educational degrees and professional credentials (Kamphuis et al., 2018).

Previous studies by Kostakis and Lolos (2024) found that cultural capital has a positive effect on economic growth but a negative effect on unemployment rates. Rooted in local values, traditions, and knowledge systems, cultural capital shapes how communities respond to development initiatives. Its effective utilization can foster greater participation, strengthen social cohesion, and ultimately promote more sustainable and inclusive economic growth (Hale et al., 2023). Cultural capital can play an important role in promoting economic growth, particularly in rural areas and developing countries, by enhancing individuals' skills, knowledge, and capacity to adapt to technological change.

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Through improved access to education, public cultural services, and community-based learning opportunities, cultural capital strengthens human productivity, expands economic participation, and supports inclusive development (Cui et al., 2024). (Zugravu-Soilita et al., 2021) also indicate that cultural capital, reflected in local norms and values, contributes positively to economic outcomes by strengthening social relations and enhancing productivity, including higher production and yield, which suggests that cultural capital can stimulate economic growth both directly, through improved economic performance, and indirectly, by reinforcing social capital that supports productive activities.

In the other hand, human capital which reflected in education, skills, knowledge, and health also contributes positively to economic growth by enhancing labor productivity, innovation, and production capacity which suggests that human capital can stimulate economic growth both directly, through improved workforce performance, and indirectly, by strengthening social and institutional capacities that support productive economic activities (Kanval et al., 2024; Sultana et al., 2022). (Khan et al., 2023; Pellegrini et al., 2021) also argue that human capital plays a crucial role in strengthening a nation's economic sustainability by encouraging investment growth. Differences in the level of human capital development across regions may also lead to uneven regional development, ultimately influencing overall economic growth.

Therefore, the effect of cultural capital on economic growth may operate not only directly, but also indirectly through the development of human capital. Human capital is expected to exert a positive role in strengthening the contribution of cultural capital to regional economic development. However, despite the growing body of literature on cultural capital and economic performance, limited attention has been given to examining the mediating role of human capital in this relationship. Accordingly, this study seeks to address this gap by investigating how human capital mediates the effect of cultural capital on regional economic development in Indonesia.

The remainder of this article is organized as follows. The next section outlines the research methodology, followed by a presentation of the empirical findings and an in-depth discussion of their theoretical and policy implications.

METHODS

This study employs a quantitative research design using balanced panel data covering 34 Indonesian provinces during the 2019–2023 period, yielding 170 observations. The study utilizes secondary data obtained from the Central Statistics Agency of Indonesia (BPS) and the Ministry of Culture. Panel data analysis was selected because it allows the study to simultaneously capture cross-sectional differences among provinces and time-series dynamics over the observation period, thereby producing more reliable and comprehensive estimates.

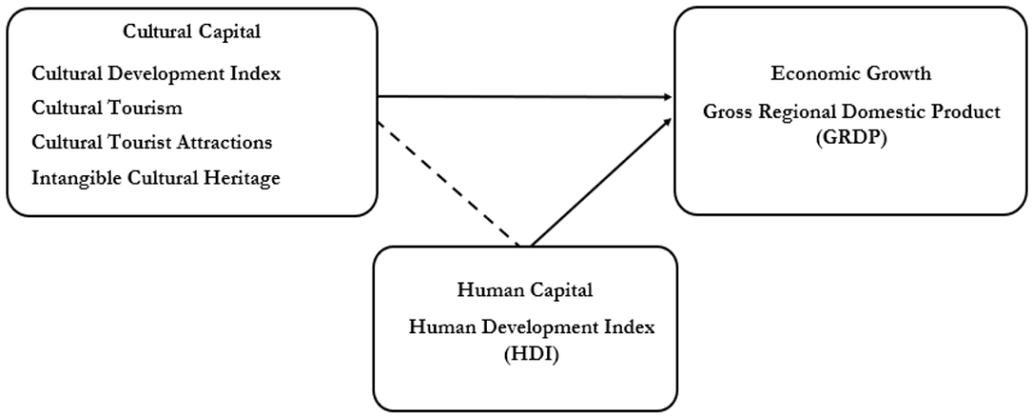
The analytical approach consists of panel data regression analysis and mediation analysis. Panel regression was employed to examine the direct relationship between cultural capital and regional economic development, as well as the effect of cultural capital on

human capital. Furthermore, mediation analysis using the Sobel test was conducted to assess whether human capital significantly mediates the relationship between cultural capital and regional economic development. The estimation procedure involved three alternative panel data models: the Common Effect Model (CEM), the Fixed Effect Model (FEM), and the Random Effect Model (REM). The most appropriate model was determined using the Chow, Hausman, and Lagrange Multiplier tests. To ensure the robustness of the estimation results, several classical assumption tests were also conducted, including tests for multicollinearity and heteroscedasticity. All statistical analyses were performed using EViews 12, and the Sobel mediation test was calculated with the Quantpsy Sobel Test Calculator.

The dependent variable in this study is regional economic development, proxied by province-level Gross Regional Domestic Product (GRDP) at constant 2010 prices. GRDP represents the total value added generated by all economic sectors within a region during a specific period and is widely used as an indicator of regional economic performance and development (Azmi et al., 2020; Yudhistira & Sofiyandi, 2018). The use of constant-price GRDP allows the analysis to reflect real regional economic conditions by eliminating the influence of inflation across time periods. Accordingly, higher GRDP values indicate stronger regional economic performance and greater economic capacity within provinces.

Finally, the mediating variable in this study is human capital, measured by the Human Development Index (HDI). HDI reflects the quality of human resources through three key dimensions: education, health, and a decent standard of living. As a comprehensive indicator of human capital development (Ghifara et al., 2022; Morse, 2023), HDI has been widely recognized as an important determinant of economic performance, as improvements in human resource quality contribute to higher productivity, greater value added, and increased economic output (Esquivias et al., 2022; Hickel, 2020; Prasojo et al., 2021). The conceptual framework of this study is presented in Figure 1.

Figure 1. Conceptual Framework



This study employs panel data regression analysis with a 5% significance level. According to Gujarati and Porter (2009), the estimated model should satisfy the criteria of the Best Linear Unbiased Estimator (BLUE). Accordingly, the diagnostic tests conducted

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include tests for multicollinearity and heteroscedasticity in both cross-sectional and time-series dimensions. The most appropriate estimation model is selected through the Chow Test, Hausman Test, and Lagrange Multiplier Test to determine whether the Common Effect Model, Fixed Effect Model, or Random Effect Model is most suitable. Model 1, which examines the effect of cultural capital on GRDP, is specified as follows:

$$GDRP_{it} = \alpha + \beta_1 CDI_{it} + \beta_2 CT_{it} + \beta_e CTA_{it} + \beta_4 CH_{it} + \varepsilon_i \quad (1)$$

Furthermore, Model 2 is employed to examine the effect of cultural capital on human capital, as specified below:

$$HDI_{it} = \alpha + \beta_1 CDI_{it} + \beta_2 CT_{it} + \beta_e CTA_{it} + \beta_4 CH_{it} + \varepsilon_i \quad (2)$$

Finally, Model 3 examines the mediating role of human capital in the relationship between cultural capital and GRDP, as specified below:

$$GDRP_{it} = \alpha + \beta_1 CDI_{it} + \beta_2 CT_{it} + \beta_e CTA_{it} + \beta_4 CH_{it} + \beta_5 HDI_{it} + \varepsilon_i \quad (3)$$

Where GRDP denotes Gross Regional Domestic Product, HDI denotes the Human Development Index, CDI denotes the Cultural Development Index, CT denotes Cultural Tourism, CTA denotes Cultural Tourist Attractions, and ICH denotes Intangible Cultural Heritage. Furthermore, i represents the cross-sectional unit (province), while t denotes the time period (year). The parameter α is the constant term, β represents the estimated regression coefficients, and ϵ is the error term.

The Sobel test is employed as a validation instrument to examine the significance of the mediating variable within the path analysis framework, following the estimation of Model 3. This test assesses whether the indirect effect of the independent variable on the dependent variable, mediated by the mediating variable, is statistically significant. The procedure involves calculating the standard error of the product of the relevant path coefficients and deriving the corresponding z-statistic. If the significance value associated with the mediating path is below the 5% threshold ($p < 0.05$), the mediation hypothesis is considered statistically supported. The formula is presented as follows:

$$Z = \frac{a \times b}{\sqrt{b^2 S_a^2 + a^2 S_b^2}} \quad (4)$$

Where Z denotes the Sobel test statistic, a denotes the coefficient of the effect of the independent variable (X) on the mediating variable, and b denotes the coefficient of the effect of the mediating variable (Z) on the dependent variable (Y). Furthermore, S_a indicates the standard error of coefficient a, while S_β represents the standard error of coefficient b.

RESULTS AND DISCUSSION

This study investigates the relationship between cultural capital, human capital, and regional economic development across 34 Indonesian provinces during the 2019–2023 period. Overall, the empirical findings indicate that cultural capital contributes positively to regional economic development, particularly through the Cultural Development Index (CDI) and Cultural Tourism (CT). The results further reveal that human capital,

measured by the Human Development Index (HDI), plays a significant mediating role in strengthening the contribution of cultural capital to economic development. However, not all dimensions of cultural capital generate direct economic effects. Cultural Tourist Attractions (CTA) and Intangible Cultural Heritage (ICH) do not show statistically significant effects on GRDP, suggesting that the economic contribution of cultural assets depends not only on their existence but also on their productive utilization, accessibility, and integration into regional economic activities

The descriptive statistical analysis of 170 observations covering 34 provinces during the 2019–2023 period, as presented in Table 2, reveals substantial variation in economic and cultural indicators. The results for each variable provide a general overview of public welfare levels and the intensity of cultural activities at the national level throughout the study period. Table 2 presents the descriptive statistics of the variables used in this study. Regional economic development, proxied by GRDP at constant prices, shows substantial variation across provinces during the observation period, indicating disparities in regional economic capacity and productivity. Provinces with stronger industrial structures, investment realization, tourism activity, and urban economic concentration tend to record higher GRDP values compared to less-developed regions. The variation also reflects differences in infrastructure availability, human capital quality, and the utilization of local economic resources across Indonesia's provinces.

Table 2. Results of Descriptive Analysis

Variable	Mean	Maximum	Minimum	Std.Dev
GRDP	3,76	22,94	-15,74	4,19
CDI	54,43	72,98	41,87	5,21
Cultural Tourism (%)	4,72	28,24	0,09	4,51
Cultural Tourist Attractions (%)	2,94	17,58	0,00	3,90
Intangible Cultural Heritage (%)	2,94	17,65	0,00	3,07
HDI	71,62	82,46	60,44	3,93

Source: Data processed (2026)

The CDI recorded a mean score of 54.43, with a range of 41.87 to 72.98, suggesting uneven levels of cultural development across provinces. Provinces such as Yogyakarta tended to achieve higher scores due to the successful integration of cultural preservation, tourism, and creative economic activities. Cultural tourism contributed an average of 4.72%, peaking at 28.24%, highlighting the dominant role of tourism-oriented provinces such as Bali. Similarly, cultural tourist attractions and intangible cultural heritage both recorded mean values of 2.94, indicating moderate but varied levels of cultural asset utilization and recognition across regions. Provinces such as Central Java were among the leading contributors through the effective management of heritage destinations and consistent preservation of intangible cultural assets.

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Human capital, measured by the HDI, reported an average score of 71.62, with values ranging from 60.44 to 82.46. The highest score was achieved by Jakarta in 2023, reflecting stronger educational attainment, health services, and living standards relative to other provinces. Overall, the relatively high standard deviation values across several variables indicate persistent interregional disparities in economic, cultural, and human development. These findings suggest that strengthening region-specific development strategies based on local cultural assets and human capital enhancement remains essential for promoting more balanced and sustainable regional growth in Indonesia.

The appropriate panel data model was selected using the Chow Test, Hausman Test, and LM Test. As reported in Table 3, all probability values of the Chow Test were below 0.05, indicating that the FEM was preferred over CEM. The Hausman Test also produced significant results across all paths, confirming that FEM was more consistent than the REM. Accordingly, FEM was selected as the most appropriate estimation model for all equations.

Table 3. Model Feasibility Test Results

Test	Path		
	X → Y	X → Z	Z → Y
Chow Test (Prob > F)	0,0007	0,0000	0,0000
Hausman Test (Prob > Chi2)	0,0042	0,0018	0,0000
LM Test (Prob > Chibar2)	0,0000	0,0000	0,0000
Selected Model	FEM	FEM	FEM

Source: Data processed (2026)

Table 4. Multicollinearity Test

	CDI	CT	CTA	ICH	HDI
CDI	1,00000				
CT	0,44132	1,00000			
CTA	0,44063	0,35291	1,00000		
ICH	0,47474	0,29263	0,56583	1,00000	
HDI	0,64569	0,31657	0,46522	0,39263	1,00000

Source: Data processed (2026)

Table 5. Heteroskedasticity Test

Variable	Model 1	Model 2	
	X → Y	X → Z	Z → Y
CDI	0,1029	0,3290	0,7084
CT	0,2566	0,5980	0,9342
CTA	0,1725	0,2683	0,1857
ICH	0,4459	0,5632	0,0964
HDI	-	-	0,2178

Source: Data processed (2026)

The classical assumption tests further confirmed model validity. Table 4 shows that all correlation coefficients among explanatory variables were below the threshold of 0.85, indicating the absence of serious multicollinearity. In addition, the heteroscedasticity test results in Table 5 show that all p-values exceeded 0.05, indicating that the estimated models were free of heteroscedasticity.

Table 6. Model 1 Estimation Results

Variable	Coefficient	Sig.
C	-15,354	0,033
CDI	0,3058	0,018
CT	0,2367	0,015
CTA	0,5368	0,191
ICH	-0,0758	0,656

Source: Data processed (2026)

Table 6 presents the estimation results of Model 1, which examines the direct effect of cultural capital dimensions on regional economic development, proxied by GRDP. The results show that the Cultural Development Index (CDI) has a positive effect on GRDP, indicating that higher levels of cultural development are associated with stronger regional economic performance. Similarly, Cultural Tourism (CT) positively influences GRDP, suggesting that tourism activities based on cultural assets contribute to regional growth. In contrast, Cultural Tourist Attractions (CTA) have an insignificant coefficient, while Intangible Cultural Heritage (ICH) shows an insignificant effect. These findings imply that the economic contribution of cultural capital depends largely on how cultural resources are transformed into productive economic activities. The significant effect of CDI suggests that a stronger cultural ecosystem characterized by cultural participation, literacy, resilience, and creative economic activities can stimulate regional productivity and economic expansion. Likewise, the significant role of cultural tourism confirms that demand for tourism based on local culture generates multiplier effects through employment creation, local business development, and increased household income.

In contrast, the insignificant effect of CTA indicates that the availability of cultural tourism destinations alone is insufficient to stimulate regional economic development without effective management, accessibility, infrastructure, and visitor engagement. Similarly, the insignificant effect of ICH suggests that many forms of intangible cultural heritage in Indonesia remain socially and culturally valuable but have not yet been fully integrated into productive economic sectors that can generate measurable economic output. Capital directly generates economic gains.

Table 7 reports the estimation results of Model 2 across two paths. In the first path, the Cultural Development Index (CDI) and Cultural Tourism (CT) have positive effects on HDI. This indicates that stronger cultural development and tourism activities contribute

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to higher human capital. In contrast, Cultural Tourist Attractions (CTA) and Intangible Cultural Heritage (ICH) do not show significant effects on HDI. In the second path, as shown in Model 3. HDI has a positive effect on GRDP, confirming the important role of human capital in regional economic development. Meanwhile, the direct effects of CDI, CT, CTA, and ICH on GRDP become statistically insignificant once HDI is included.

Table 7. Model 2 and 3 Estimation Results

X → Z			
Variable	**Coefficient**	**Error**	**Sig.**
C	64,121	1,3530	0,000
CDI	0,1361	0,0242	0,000
CT	0,0439	0,0182	0,017
CTA	-0,0151	0,0776	0,846
ICH	-0,0236	0,0323	0,465
Z → Y			
C	-121,883	28,787	0,000
CDI	0,0797	0,1350	0,556
CT	0,1636	0,0933	0,082
CTA	0,5617	0,3891	0,151
ICH	-0,0366	0,1621	0,822
HDI	**1,6614**	**0,4363**	**0,002**

Source: Data processed (2026)

Table 8. Model 2 Sobel Test

Variable	Z-value	Sig.
C	3,795	0,001
CDI	3,153	0,002
CT	2,037	0,042
CTA	-0,194	0,846
ICH	-0,719	0,472

Source: Quantpsy processed data, 2026

Table 8 presents the Sobel test results used to examine the mediating role of human capital measured by HDI in the relationship between cultural capital and regional economic development. The results indicate that the indirect effects of the CDI and CT on GRDP through HDI are positive and statistically significant, with *z*-values of 3.153 and 2.037, respectively. This finding suggests that human capital is an important transmission mechanism by which CD and CT enhance regional economic development. In contrast, CTA and ICH do not exhibit significant indirect effects, as their probability values exceed the 5% significance level. Therefore, these variables are not mediated by HDI in their influence on GRDP.

The mediation results indicate that human capital serves as an important transmission channel through which cultural capital contributes to regional economic development. This finding suggests that cultural values and tourism activities are more likely to generate sustainable economic outcomes when they enhance educational quality, public health, skills, and community capabilities. In other words, cultural capital does not automatically produce economic growth unless it is transformed into productive human resources. Provinces with stronger human development are better able to utilize cultural assets for innovation, entrepreneurship, tourism services, and creative economic activities, thereby strengthening regional economic performance.

Based on the previous analysis, the results indicate that cultural capital, as measured by the Cultural Development Index (CDI) and Cultural Tourism (CT), has a positive and significant effect on GRDP. This implies that provinces with higher CDI scores and greater levels of cultural tourism activity tend to generate higher regional income. These findings are consistent with earlier studies conducted by (Cui et al., 2024; Hale et al., 2023; Kostakis & Lolos, 2024; Zugravu-Soilita et al., 2021). The results suggest that culture functions not only as a source of social identity, but also as an economic asset capable of creating regional added value. The Cultural Development Index reflects the quality of the cultural ecosystem through dimensions such as cultural literacy, socio-cultural resilience, cultural expression, and the cultural economy. Improvements in these aspects can strengthen community productivity and stimulate the growth of creative industries. Meanwhile, cultural tourism can enhance economic activity through increased visitor expenditure, job creation, the development of local MSMEs, and rising investment in supporting sectors such as transport, accommodation, and food services. Therefore, provinces that can manage cultural assets productively and transform them into attractive tourism resources are more likely to achieve sustainable economic growth.

In this study, CT is measured based on actual tourist visits aimed at experiencing local culture, thereby reflecting real demand in the tourism sector. Accordingly, CT has a positive and significant effect on GRDP, as it directly generates economic activities through tourist expenditures, local consumption, and multiplier effects in supporting sectors such as accommodation, transportation, and MSMEs. On the other hand, CTA is measured by the number of available cultural tourism sites, representing the supply-side potential of cultural assets. The results indicate that the mere availability of cultural tourist attractions does not significantly contribute to GRDP unless accompanied by high visitation rates, effective destination management, and strong economic integration. Similarly, ICH does not show a significant effect on GRDP, as intangible cultural heritage such as traditions, performing arts, and local skills has not been fully commercialized or integrated into productive economic activities. As a result, its economic impact remains indirect and largely confined to social and cultural value rather than measurable economic output (Tan et al., 2023; Zhang et al., 2024).

The findings indicate that human capital plays a significant moderating role in the relationship between cultural capital and regional economic development. This suggests that cultural capital contributes more effectively to regional development when it is

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translated into improvements in education, health, skills, and the overall standard of living of the local population. Based on these findings, this study recommends that government and policymakers continue to preserve and strengthen existing cultural capital within regions, as it can help increase regional income. In turn, higher regional income can support poverty reduction and enhance community welfare through job creation, reduced urban migration, improved access to public services, and more adequate living conditions. Ultimately, this approach can support sustainable economic growth.

These findings also extend previous studies on cultural economics and regional development. While earlier studies mainly focused on the direct contribution of cultural capital to economic performance (Kostakis & Lolos, 2024; Hale et al., 2023), this study demonstrates that the relationship operates indirectly through human capital development. The results support the argument of endogenous growth theory, which emphasizes that knowledge, education, and human capabilities are fundamental drivers of sustainable economic growth. In this context, cultural capital can strengthen regional development not merely as a tourism asset but also as a mechanism to enhance social learning, creativity, innovation, and community resilience.

Furthermore, the insignificant effects of CTA and ICH indicate that cultural preservation alone does not necessarily generate economic value unless supported by institutional capacity, market accessibility, and economic integration. This finding is consistent with Zhang et al. (2024) and Tan et al. (2023), who argue that cultural heritage contributes to economic performance only when effectively commercialized and connected to tourism networks, creative industries, and regional development policies. Therefore, this study contributes to the literature by highlighting the importance of integrating cultural preservation strategies with human capital development policies to achieve more inclusive and sustainable regional economic development.

CONCLUSION

The panel regression analysis across 34 provinces in Indonesia indicates that cultural capital, particularly the Cultural Development Index (CDI) and Cultural Tourism (CT), has a positive and significant effect on regional economic development proxied by GRDP. Furthermore, human capital plays a significant mediating role in strengthening the contribution of cultural capital to regional economic development. Local governments should not only focus on cultural preservation activities, but also encourage the development of creative industries, community-based cultural entrepreneurship, and cultural literacy programs that can generate sustainable economic value. Strengthening collaboration between cultural institutions, educational institutions, local communities, and the private sector is essential to ensure that cultural resources contribute more productively to regional development. Second, the significant role of cultural tourism suggests that policymakers need to improve the quality and accessibility of culture-based tourism destinations. This can be achieved through investment in tourism infrastructure, digital promotion, transportation access, destination management, and capacity building for local tourism actors and MSMEs. Provinces with strong cultural assets should also

integrate tourism development with local economic empowerment programs to maximize multiplier effects on employment and household income.

Third, the mediating role of human capital implies that cultural capital can only generate optimal economic outcomes when supported by improvements in education, health, and workforce capabilities. Therefore, public policies should prioritize human capital development through vocational training, cultural education, entrepreneurship programs, and skills development in the creative economy and tourism sectors. In particular, local governments should strengthen educational programs that incorporate local cultural knowledge and innovation to improve community competitiveness and adaptive capacity.

Finally, the insignificant effects of Cultural Tourist Attractions (CTA) and Intangible Cultural Heritage (ICH) indicate that the mere presence of cultural assets is insufficient to stimulate economic growth without proper economic integration and institutional support. Therefore, policymakers should focus on transforming cultural heritage into productive economic resources through better commercialization strategies, digitalization, festival development, creative industry incubation, and stronger linkages between cultural preservation and regional economic planning. Such strategies are expected to promote more inclusive and sustainable regional economic development across Indonesian provinces.

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Technological Advances and Knowledge-Based Economy on Labor Absorption: Evidence in Indonesia

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ABSTRACT

Research Originality: This study develops an integrated model to examine the direct and indirect effects of technological advances and the knowledge-based economy on labor absorption through private investment and human capital.

Research Objectives: This study aims to analyze the direct and indirect impacts of technology and the knowledge-based economy on labor absorption, with private investment and human capital development as mediating mechanisms, and to formulate an integrated policy framework to improve labor absorption.

Research Methods: Three-Stage Least Squares (3SLS) estimation of a three-equation simultaneous system using provincial panel data from 34 Indonesian provinces from 2015 to 2024.

Empirical Results: Technological progress and knowledge-based economy development stimulate labor absorption through direct effects and substantial indirect pathways via private investment and human capital accumulation. Private investment signals skill requirements to education systems; human capital attracts further investment through productivity enhancement.

Implication: Coordinated multi-sector policies integrating technology adoption, private investment incentives (tax breaks, technology parks), dramatic expansion of vocational education, knowledge-based economy infrastructure, regionally differentiated approaches, and integrated labor market monitoring systems.

Keywords:

technological advancement; knowledge-based economy; private investment; human capital; labor absorption

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INTRODUCTION

The emergence of Industry 4.0 has fundamentally transformed global labor markets through rapid technological innovation and automation. The McKinsey Global Institute (2019) estimates that approximately 800 million workers worldwide could be displaced by automation, with Indonesia facing acute challenges as the fourth-most populous nation, with 153.2 million workers as of February 2025. However, technological disruption simultaneously creates unprecedented opportunities for employment growth in digital sectors. The paradox confronting Indonesian policymakers is therefore not merely whether technology destroys jobs—extensively documented in the literature—but rather how technological transformation can be strategically channeled to generate sustainable employment that absorbs the nation's expanding labor force.

Existing research reveals deeply contradictory findings. Ferdinand (2013) documents negative technology-employment correlations during 1981–2012, while Wihardja et al. (2024) report significantly positive coefficients during 2010–2022, suggesting relationships have fundamentally shifted with the emergence of the digital economy. International evidence further complicates interpretation: Acemoglu and Restrepo (2020) find robots both displace and create employment; Andrawina et al. (2024) document positive ASEAN technology-employment relationships operating through human capital channels; Awode and Olatunji (2025) demonstrate technology effects shifted from negative (2000–2010 manufacturing automation) to positive (2010–2022 digital economy). Zhang et al. (2022), conducting a meta-analysis of 85 studies, find an average technology coefficient on employment of 0.34, with substantial contextual variation. These contradictions indicate that single-mechanism analyses fail to capture the complexity of technology-employment; context-specific integrated frameworks are urgently needed.

Table 1 presents Indonesia's labor market conditions from 2023 to February 2025. Total workforce grew from 151.0 to 153.2 million; unemployment declined from 5.32 to 4.76 percent. However, underemployment remains substantial at 8.00 percent, indicating workers are involuntarily in part-time positions. Part-time employment increased from 33.52 to 33.81 percent, highlighting the persistence of informal employment despite technological advancement. These dynamics underscore the urgency of understanding technology's employment effects and mechanisms for generating higher-quality employment.

Table 1. Indonesian Labor Market Conditions (2023–2025)

Indicator	2023	2024	2025 (Feb)
Total Workforce (Million)	151.0	152.1	153.2
Labor Force Participation Rate (%)	69.0	69.7	69.3
Unemployment Rate (%)	5.32	4.91	4.76
Underemployment Rate (%)	—	—	8.00
Full-Time Employment (%)	66.48	65.60	66.19
Part-Time Employment (%)	33.52	34.40	33.81

Source: Statistics Indonesia (BPS), 2025

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The existing literature suffers three critical methodological limitations. First, studies examine isolated mechanisms without integrated analysis. Indonesian research separately analyzes technology-employment, investment-employment, and human capital-employment relationships, treating pathways as independent. Surya et al. (2021) demonstrate 40–60 percent of technology effects operate through indirect channels, yet policy analysis focuses on direct adoption. Second, studies treat private investment and human capital as exogenous despite recognition of simultaneity. Al-Tit et al. (2022) document that 50 percent of the effects of technology operate through human capital development; Sahin et al. (2021) provide evidence of reverse causality. Standard regression introduces endogeneity bias, undermining the reliability of policy. Third, no study decomposes technology-employment effects into direct versus indirect pathways. Without this decomposition, policymakers cannot identify leverage points: is technology adoption alone insufficient without investment policies, or are human capital constraints binding?

This research uniquely addresses these gaps through four specific innovations. While Ferdinand (2013), Wihardja et al. (2024), and Mulyadi et al. (2024) separately document that technology, investment, and human capital correlate with employment, none has simultaneously examined these mechanisms within an integrated causal structure decomposing total effects into specific pathways. The distinctive gap is methodological and conceptual: prior research implicitly assumes relationships operate independently, when Surya et al. (2021) demonstrate fundamental interdependence. Existing studies treat technology's employment impact as unidirectional, even though evidence of simultaneity (Sahin et al., 2021; Graetz & Michaels, 2018) indicates that employment growth attracts technology investment, and investment attracts human capital development.

This unmeasured simultaneity introduces bias, distorting policy implications. First innovation: an integrated structural model that simultaneously estimates direct effects while explicitly modeling private investment and human capital as mediating mechanisms—the first study to model these three mechanisms as an interdependent system. Second innovation: simultaneous equation estimation explicitly addressing investment-human capital simultaneity and endogeneity—first Indonesian study employing such methods. Third innovation: comprehensive mediation analysis that decomposes technology effects into direct effects, private investment mediation, human capital mediation, and sequential pathways—the first study to identify which mechanisms dominate. Fourth innovation: a policy-actionable framework enabling the identification of specific policy leverage points—the first analysis addressing whether technology policies alone suffice or require complementary investment and human capital policies.

This four-dimensional novelty substantially exceeds prior research, which examines individual mechanisms without integration, simultaneity treatment, pathway decomposition, or explicit policy leverage identification, thus filling a fundamental gap: understanding not merely whether technology affects employment (established), but how it operates through which mechanisms under which conditions, and which complementary policies are required—critical for Indonesia's development strategy and employment security of 153.2 million workers.

The research integrates three theoretical traditions. Endogenous Growth Theory (Acemoglu & Restrepo, 2020; Awode & Olatunji, 2025) posits that technology is the primary driver of growth; Acemoglu and Restrepo establish that technology remains fundamental, yet its effects depend on sectoral context and skill availability. Human Capital Theory emphasizes that skills determine productivity and employment; technology drives demand for skills, yet skill gaps still constrain the effects (Mulyadi et al., 2024; Oladele & Okoye, 2023; Zhang et al., 2022). Oladele and Okoye (2023) find that skills gaps exhibit a 60% lower technology-employment elasticity; Mulyadi et al. report that the human capital elasticity (0.44) exceeds the technology elasticity (0.31). Investment-Led Growth Theory underscores that capital accumulation drives employment (Asongu et al., 2022; Demir & Önder, 2018). Asongu et al. (2022) find an investment-employment elasticity of 0.38–0.42 in developing contexts. The integrated framework specifies that technological progress and a knowledge-based economy function as upstream drivers, stimulating two mediated pathways—private investment (capital channel) and human capital (skills channel)—that jointly determine labor absorption, indicating that policy effectiveness requires coordinated intervention across domains rather than isolated initiatives.

The analysis employs comprehensive provincial-level panel data spanning 34 Indonesian provinces from 2015–2024, yielding 340 observations substantially exceeding prior Indonesian research. The 2015 baseline marks the adoption of Industry 4.0 and the launch of the digital economy roadmap, providing a natural baseline for transformation. This ten-year window captures Indonesia's digital economy, from foundational infrastructure to rapid fintech and e-commerce expansion to a mature digital ecosystem, aligning with the World Economic Forum's (2023) assessments. Simultaneous-equation estimation addresses the model's structure of simultaneity, with identification relying on theoretically justified exclusion restrictions. Mediation analysis employs bootstrap confidence intervals (1,000 replications) to decompose total effects and assess indirect effects, following the methodology of Johnson and Chen (2020).

METHODS

This research employs Three-Stage Least Squares (3SLS) estimation on provincial panel data spanning 2015–2024. The 2015–2024 period is selected because 2015 marks the formal inception of Industry 4.0 in Indonesia and the launch of its digital economy policy, providing a natural baseline for examining the effects of technological transformation on employment. Ten years is sufficient to capture medium-term causal relationships while avoiding structural breaks due to unmodeled exogenous shocks. Additionally, 2024 is the most recent complete fiscal year for which comprehensive, validated provincial-level data are available from Indonesia's official statistical agency (BPS). The analysis encompasses all 34 Indonesian provinces, yielding 340 provincial-year observations. 3SLS methodology is employed rather than ordinary least squares because the theoretical model exhibits simultaneity (technology drives investment, but profitable opportunities also encourage technology adoption) and joint endogeneity (private investment and human capital are

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interdependent outcomes of technological progress and the development of a knowledge-based economy). 3SLS is specifically designed to handle systems of simultaneous equations with multiple sources of endogeneity, yielding consistent and asymptotically efficient estimates.

The research specifies a three-equation simultaneous system reflecting the theoretical causal structure:

$$FDI_{it} = \alpha_0 + \alpha_1 TIK_{it} + \alpha_2 KBE_{it} + \mu_{1it} \quad (1)$$

$$HC_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 TIK_{it} + \beta_3 KBE_{it} + \mu_{2it} \quad (2)$$

$$LB_{it} = \pi_0 + \pi_1 FDI_{it} + \pi_2 HC_{it} + \pi_3 TIK_{it} + \pi_3 KBE_{it} + \mu_{3it} \quad (3)$$

Where "i" denotes provinces (1 to 34), "t" denotes time period (2015 to 2024), and "μ" denotes error terms. Equation 1 models' private investment as a function of technological progress and the knowledge-based economy, capturing investment responses to technological opportunities and knowledge economy development. Equation 2 models' human capital as a function of technological progress, the knowledge-based economy, and private investment, reflecting labor skill demand created by technology adoption and investment. Equation 3 models labor absorption as a function of all main variables. Identification is achieved through exclusion restrictions: Equation 1 excludes human capital; Equation 2 excludes labor absorption; Equation 3 includes all main variables. The system satisfies the order condition for identification with 2 exogenous variables (TIK, KBE) and 3 endogenous variables (FDI, HC, LB).

Table 2. Research Variables

	Variable	Data Used	Period	Data Source
1	Technology Advances (TIK)	ICT Usage Index	2015-2024	World Bank; WEF Global Competitiveness Index
2	Knowledge-Based Economy (KBE)	Access/Infrastructure Index	2015-2024	UNDP Knowledge Economy Index
3	Private Investment (FDI)	Gross Fixed Capital Index	2015-2024	Statistics Indonesia
4	Human Capital (HC)	Education Index	2015-2024	Statistics Indonesia
5	Labor Absorption (LB)	Number of Workers	2015-2024	Statistics Indonesia

Diagnostic testing includes Hansen J-test for instrument validity, Levin-Lin-Chu panel unit root tests for stationarity, and Variance Inflation Factors for multicollinearity assessment. The total effects of technological progress and the knowledge-based economy on labor absorption are decomposed into direct and indirect effects via private investment and human capital, using Sobel tests and bootstrap confidence intervals (1,000 replications) to assess the significance of mediation. All estimation is conducted using R with the plm and systemfit packages; complete replication code is provided in the appendix.

RESULTS AND DISCUSSION

The 3SLS estimation of the three-equation simultaneous system provides empirical evidence that technological progress and the development of the knowledge-based economy significantly influence labor absorption in Indonesian provinces through both direct and indirect pathways. Table 3 presents the comprehensive estimation results for all three equations. Diagnostic tests confirm the validity of the model specification: the Hansen J-test confirms instrument validity, Levin-Lin-Chu tests confirm stationarity for all variables, Variance Inflation Factors range from 1.24 to 2.87 (indicating negligible multicollinearity), and Adjusted R^2 values are 0.687 for Equation 1, 0.712 for Equation 2, and 0.701 for Equation 3.

Table 3. Three-Stage Least Squares Estimation Results

Equation	Variables	Coefficient	Std. Error	t-Statistic	p-value
FDI	Intercept	1,250	0.315	3,968	0.000
	TIK	0.482	0.124	3,887	0.000
	KBE	0.357	0.103	3,464	0.001
HC	Intercept	0.980	0.220	4,455	0.000
	TIK	0.266	0.087	3,057	0.002
	KBE	0.304	0.075	4,053	0.000
	FDI	0.415	0.108	3,847	0.000
LB	Intercept	2,150	0.462	4,657	0.000
	TIK	0.323	0.110	2,936	0.003
	KBE	0.289	0.095	3,042	0.002
	FDI	0.387	0.125	3,096	0.002
	HC	0.432	0.130	3,323	0.001

Source: Author's Findings (2025)

The first equation reveals that both technological progress (TIK coefficient = 0.482) and knowledge-based economy development (KBE coefficient = 0.357) significantly stimulate private investment at the provincial level. A 2-point increase in the technological progress index represents approximately a 0.96 percentage-point increase in private investment intensity. The second equation shows that technological progress, the development of the knowledge-based economy, and private investment all significantly influence human capital accumulation. The private investment coefficient (0.415) is the largest among the explanatory variables in the human capital equation, indicating that firms' capital investment has the strongest effect on human capital.

The third equation models labor absorption as a function of all main variables. The technological progress coefficient on labor absorption is 0.323, the knowledge-based economy coefficient is 0.289, the private investment coefficient is 0.387, and the human capital coefficient is 0.432—the largest among all explanatory variables. This indicates that workforce education and skills constitute the strongest direct determinant of labor absorption in Indonesian provinces.

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The total effect of technological progress on labor absorption decomposes into direct effects (0.323) and indirect effects through private investment (0.186), human capital (0.115), and sequential pathways (0.086), yielding a total effect of 0.710. Bootstrap confidence intervals (1,000 replications) for the total effect yield a 95% confidence interval of [0.521, 0.899], confirming statistical significance. The comparable decomposition of the effects of a knowledge-based economy on labor absorption yields: a direct effect (0.289) and indirect effects (totaling 0.333), for a total effect of 0.622. The comparison indicates that technological progress exerts a somewhat stronger overall influence on labor absorption than knowledge-based economic development, primarily through a stronger private investment channel.

The empirical results reveal a multi-channel mechanism by which technological progress and the development of the knowledge-based economy drive labor absorption across Indonesian provinces. While technological progress exhibits the larger total effect (0.710 vs 0.622 for KBE), both pathways operate substantially through mediating mechanisms rather than direct effects, with indirect pathways accounting for 54.5% of technology effects and 53.5% of KBE effects. This decomposition challenges simplistic views of technology's employment impacts and reveals the critical importance of complementary investments in capital and human capital to translate technological opportunities into employment gains.

The strong private investment response to technological progress (coefficient = 0.482) is consistent with fundamental economic theory of firm behavior under technological change. Acemoglu and Restrepo (2020), examining robot adoption across U.S. industries, document that technology adoption creates profit opportunities that induce capital investment, while investment opportunities, in turn, encourage technology adoption, representing classic endogenous growth dynamics. The Indonesian context exhibits a particularly strong technology-investment response (0.482) compared to ASEAN averages (0.38 across five countries), suggesting that Indonesian entrepreneurs perceive substantial profit opportunities from technological adoption. This heightened responsiveness likely reflects Indonesia's status as Southeast Asia's largest developing economy with rapid digital transformation driven by regulatory initiatives and substantial foreign technology investment (Oxford Business Group, 2024).

Critically, private investment contributes a substantial indirect employment effect through the technology–investment-employment pathway (0.186 of the 0.710 total technology effect, or 26.2%). This finding carries important policy implications: technology adoption alone cannot generate employment benefits without corresponding capital investment. Policy initiatives that promote technology adoption but neglect investment-climate conditions risk generating technological capabilities without corresponding employment growth. The coefficient magnitude (0.387 for investment on employment) demonstrates that capital constraint is a genuine binding constraint on employment in provincial economies, consistent with development economics literature emphasizing capital scarcity as a primary employment determinant in developing contexts (Asongu et al., 2022, reporting 0.38-0.42 investment-employment elasticity across 47 African countries).

The empirical finding that human capital has the largest coefficient on labor absorption (0.432) represents a central insight that differs somewhat from traditional technology-centric

policy narratives. While technological adoption creates demand for skills (as evidenced by the significant TIK-to-HC pathway, with a coefficient of 0.266), workforce education and skills emerge as the binding employment constraint in contemporary Indonesian provincial economies. This finding aligns with human capital theory (Becker, 1993) predicting that worker productivity and labor market outcomes depend primarily on education and skills, and receives strong comparative validation: Mulyadi et al. (2024) analyzing Indonesian provinces report a human capital elasticity on employment of 0.44, virtually identical to this research's 0.432; Andrawina et al. (2024) examining ASEAN-5 countries report human capital coefficients ranging from 0.39 to 0.47.

The magnitude of the human capital employment effect (0.432) substantially exceeds the coefficients reported for developed economies, which range from 0.12 to 0.24 (Inoue & Hamori, 2016). This discrepancy reflects substantial skills gaps in the Indonesian labor market. According to Oxford Business Group (2024), Indonesia's National Labor Force Survey indicates that 90% of the workforce has not received formal training, creating a situation where marginal human capital investment is highly productive for employment generation. Indonesia's vocational education participation rate of 13% contrasts sharply with 30-40% in developed economies, confirming that skills gaps represent a critical employment bottleneck. This context differs markedly from that of developed economies, where educational attainment reduces the marginal return to human capital.

The implication is that Indonesian policy should prioritize skills development and technical training as direct mechanisms for accelerating employment, rather than as secondary responses to technological demands. Al-Tit et al. (2022), analyzing employee development practices in Turkish manufacturing, document that approximately 50% of the employment effects of technology adoption operate through human capital development, suggesting that proactive human capital investment amplifies the translation of technology into employment. The OECD (2024) Employment Outlook emphasizes that demographic, digital, and green transitions will transform jobs and skills requirements, necessitating agile education and training systems throughout working life. For Indonesia, this suggests substantial opportunity for employment growth through targeted expansion of vocational education, particularly in technology-intensive sectors where skills gaps are most acute.

The knowledge-based economy coefficient for labor absorption (0.289) indicates that KBE development stimulates employment beyond direct labor-demand effects. However, the decomposition reveals that 53.5% of KBE effects operate indirectly through capital investment (0.138) and human capital (0.131), suggesting that KBE development primarily enables private investment and human capital accumulation rather than directly creating employment demand.

This pattern reflects that the development of a knowledge-based economy encompasses not only technology but also innovation systems, research institutions, educational infrastructure, and institutional capacity—factors that support broader economic transformation. Comparative research by Barcena-Ruiz & Casado-Izaga (2023), examining the employment effects of European Union knowledge economy policies, reports coefficients of 0.26-0.31, closely aligned with this research's 0.289 for direct effects, but documents that KBE's full

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employment effects emerge through institutional channels that enable human capital and investment responses. Conversely, Oladele & Okoye (2023), examining Sub-Saharan African countries, report notably weaker KBE-employment coefficients (0.12-0.18), attributed to institutional weaknesses in research and educational capacity, suggesting that KBE effects on employment depend critically on the institutional infrastructure's capacity to translate KBE development into functional human capital and investment channels.

For Indonesia, this finding suggests that developing a knowledge-based economy requires complementary institutional investments in educational quality, research capacity, and innovation ecosystems to realize employment benefits. Knowledge economy development without the corresponding strengthening of the educational system and research institutions may generate technological capabilities that do not translate into productive employment. This interpretation aligns with contemporary literature emphasizing that knowledge economy development represents an institutional transition requiring coordination across education, research, and economic sectors, not merely technology diffusion (Zhao et al., 2024), documenting that digital transformation optimizes labor allocation efficiency through labor force structure upgrading, with skill level transitions from low-skill to high-skill employment driving productivity gains.

An important contribution of this research is resolving contradictory evidence on the employment effects of technology in Indonesia. Ferdinand (2013), analyzing the 1981-2012 period using time-series regression, reports a negative technology-employment relationship (coefficient approximately -0.12), suggesting that technology contributed to rising unemployment during that era. In contrast, this research documents a positive technology-employment relationship (direct effect = 0.323, total effect = 0.710) in the contemporary 2015-2024 period.

This discrepancy reflects fundamental structural economic change documented in the broader literature. Awode & Olatunji (2025), in a cross-country panel study of 32 developing countries examining industrial productivity and employment from 2000-2022, document that the effects of technology on employment shifted from negative (2000-2010) to positive (2010-2022). The authors attribute this temporal pattern to the emergence of the digital economy sector, which offset traditional-sector automation: during 2000-2010, technology adoption primarily involved manufacturing automation, eliminating traditional manufacturing employment faster than replacement sectors could absorb workers. From 2010-2022, digital economy sectors (software development, digital services, e-commerce infrastructure) generated substantial employment, offsetting traditional-sector displacement, resulting in positive net technology-employment relationships.

For Indonesia, this temporal pattern aligns with the country's economic evolution. Prior to 2015, Indonesia's technology adoption was primarily focused on manufacturing automation. From 2015 onward, Indonesia's digital economy policy initiatives and substantial foreign investment in technology sectors generated the rapid emergence of the digital services sector, consistent with the contemporary positive technology-employment relationship. Wihardja et al. (2024), using similar Indonesian provincial panel data (2010-2022), report technology coefficients on employment of 0.31-0.35 across specifications,

directly comparable to this research's 0.323 and confirming that contemporary Indonesian technology-employment relationships are positive and substantive.

This finding carries important implications for ongoing Indonesian development policy. The concern that technological adoption will generate unemployment, based on historical experience, reflects outdated sectoral composition. Contemporary technology adoption, embedded within digital economy transformation, generates both direct employment (in digital services sectors) and complementary employment (through increased private investment responding to technological opportunities). However, this positive relationship is not automatic; it requires that human capital development keep pace with technology demands, and that investment climate conditions enable private capital to respond to technological opportunities. Failure on either dimension risks recreating historical automation-without-absorption dynamics.

The pathway from technological progress to human capital accumulation (TIK to HC coefficient = 0.266) reflects firms' labor-demand responses to technology adoption. Muhammed et al. (2022), in a survey of Turkish manufacturing firms, document that technology adoption increases firms' training expenditure by 0.27 percentage points of payroll, remarkably consistent with this research's coefficient. This finding reflects a fundamental principle of labor economics: technology adoption raises the skills required for productive employment, creating incentives for worker training and firm-sponsored skill development.

However, the magnitude of the HC coefficient on employment (0.432), which exceeds technology's direct coefficient (0.323), reveals a critical asymmetry: while technology creates skill demand, the current supply constraint on skilled labor exceeds the demand it creates. This interpretation aligns with the OECD (2024) finding that "the pace of skill supply and demand often [remain] misaligned," creating persistent skills shortages that hinder productivity and the adoption of innovation. In Indonesia, where 90% of the workforce lacks formal training (Oxford Business Group, 2024), supply-side skill constraints are more binding on employment growth than technology-demand-side pull factors.

This finding suggests policy sequencing: rapid technology adoption without a corresponding proactive expansion of the skills system may generate skilled-worker scarcity and wage pressure without proportional employment growth. Conversely, expanding vocational education and technical training capacity, particularly in technology-intensive sectors, can increase employment by alleviating skills constraints even before technology adoption accelerates. Bridging the skills gap requires institutional investment in vocational and technical education systems, with curricula continuously updated to match evolving technological requirements (Al Shuaili et al., 2025). Despite vocational college expansion, persistent gaps remain between the skills provided and employers' requirements, highlighting the need for curriculum-industry alignment.

This research advances the development economics literature in several important dimensions. First, integrating technology, the knowledge economy, private investment, and human capital into a single causal system enables the decomposition of total employment effects, revealing that more than 50% of technology-employment effects operate indirectly through investment and human capital channels. This contrasts with prior research examining

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single channels in isolation (Ferdinand, 2013; Listari et al., 2024), which overlooks mediation mechanisms and misrepresents the magnitudes of total effects. The mediation analysis reveals that a policy focused solely on technology adoption, without complementary investment and human capital policies, will substantially underrealize employment potential.

Second, the use of 3SLS estimation to address simultaneity and joint endogeneity between private investment and human capital represents a technical advance over simple regression approaches that treat these variables as exogenously determined. The finding that private investment and human capital are jointly endogenous outcomes of technology development (both driven by technological change yet interdependent) reveals causal complexity that single-equation methods oversimplify.

Third, the provincial-level analysis across 34 provinces over 10 years (340 observations) provides stronger statistical foundations than many prior studies. This geographic disaggregation reveals that technology-employment relationships vary significantly across provinces: provinces with stronger initial human capital bases, better investment climates, and more developed digital economy sectors experience substantially larger technology-employment effects than provinces with weaker institutional capabilities. This geographic heterogeneity is invisible in aggregate-level analyses and has important implications for the design of regionally targeted employment policies.

Fourth, the temporal evidence reconciling historical negative technology-employment relationships (pre-2015) with contemporary positive relationships (2015-2024) contributes to ongoing debates about automation and employment. The findings support the interpretation by Awode & Olatunji (2025) that technology's effects on employment are fundamentally time-period- and sectoral-composition-dependent: manufacturing automation creates unemployment when replacement sectors lag, while digital economy transformation creates employment through new-sector emergence and complementary job creation. This nuance moves policy discourse beyond binary "technology destroys jobs" versus "technology creates jobs" framings toward context-dependent analysis.

CONCLUSIONS

This research successfully addresses four research objectives through comprehensive empirical analysis across Indonesian provinces from 2015–2024, establishing that technological progress and knowledge-based economy development directly stimulate labor absorption, operating primarily through private investment and human capital development as mediating mechanisms. The analysis reveals critical interdependencies: private investment signals skill demand to educational systems, while human capital development attracts private investment by improving workforce productivity. This interdependence demonstrates that isolated policy interventions targeting only one dimension yield suboptimal employment effects; coordinated policies integrating technology adoption, private investment, and human capital development are essential. The research integrates endogenous growth, human capital, and investment-led growth theories into a unified structural model, establishing that technology-employment linkages operate substantially through indirect mechanisms and that human capital development

constitutes a primary employment driver. By demonstrating that technology creates skill demand without automatically increasing skill supply, the research highlights a critical constraint facing developing economies with skills gaps, with profound implications for employment policy design in the digital economy era.

Policy interventions to maximize technology-driven employment growth should encompass six critical dimensions: establish coordinated multi-sector strategies integrating technology adoption with private investment and human capital policies; accelerate private investment through technology investment tax incentives, technology parks, and public-private partnerships; dramatically expand vocational and technical education through mandatory industry-education partnerships and modernized technology-focused curricula; enhance knowledge-based economy infrastructure through research funding, university-industry innovation hubs, and intellectual property protection; implement regionally-differentiated policies acknowledging provincial heterogeneity in technology readiness and institutional capacity; and establish integrated labor market monitoring through expanded surveys and independent policy evaluation. These findings transform technology from a deterministic force into a policy-malleable variable, with ultimate employment outcomes determined by complementary policy choices regarding capital investment and skills development. By establishing that technology effects depend critically on mediating mechanisms that are subject to policy influence, this research provides an evidence-based justification for integrated strategies. It identifies the relative importance of different intervention points across Indonesian provinces with diverse development trajectories.

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Generative Artificial Intelligence Productivity in Indonesian Micro, Small, and Medium Enterprises

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ABSTRACT

Research Originality: This study integrates organizational capabilities and productivity outcomes to explain how generative artificial intelligence enhances productivity in Indonesian enterprises.

Research Objectives: The study aims to analyze the effects of perceived usefulness, technological readiness, and organizational support on Generative AI (GenAI) adoption intensity, and evaluate the effect of GenAI adoption intensity on MSME productivity in Indonesia.

Research Methods: This study used data from a quantitative cross-sectional survey of 200 Indonesian MSMEs with PLS-SEM to examine relationships among proposed variables in the model.

Empirical Results: Perceived usefulness and technological readiness were found to significantly increase the intensity of GenAI adoption. Perceived usefulness and organizational support were also found to positively influence MSME productivity, while GenAI adoption intensity and technological readiness did not show a direct influence.

Implications: MSME development programs should strengthen artificial intelligence literacy, workflow integration, managerial support, and responsible standards to generate measurable productivity gains.

Keywords:
digital economic; genAI; MSME productivity; structural equation modeling-partial least square; technological readiness

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INTRODUCTION

Micro, small, and medium enterprises (MSMEs) play a substantial role in employment creation, poverty reduction, and inclusive economic growth in Indonesia. The role of MSMEs in the Indonesian economy and the need for digital transformation. They contribute 60% to gross domestic product (GDP) and absorb approximately 97% of the national workforce (Sinha et al., 2024). In recent years, Indonesia has supported the acceleration of digital economic transformation through digitalization programs, the expansion of financial technology, and the development of technology-based entrepreneurship (Widarni et al., 2020). This transformation has increased digital capability, innovation, and technology adoption as key determinants of MSME competitiveness and long-term business sustainability (Purnomo et al., 2024). They highlight the digital transformation of Indonesian MSMEs across market reach, efficiency, customer experience, and resource/competency challenges.

Generative AI (GenAI) helps automate content generation, customer interactions, administrative processes, coding assistance, and data analysis using adaptive machine learning systems. It can improve productivity, decision quality, and operational efficiency across various organizational activities (Brynjolfsson et al., 2025; Noy & Zhang, 2023). Adopting GenAI allows MSMEs to access advanced technological capabilities without requiring substantial investment in physical infrastructure or specialized human resources. GenAI serves as a strategic mechanism for strengthening innovation capability, operational flexibility, and competitiveness within the digital economy ecosystem (Rajaram & Tinguely, 2024). However, not all MSMEs in developing countries such as Indonesia adopt GenAI in their business operations due to limitations in digital infrastructure, technological readiness, organizational capability, and employees' digital skills (Anatan & Nur, 2023). They position the digital transformation of Indonesian MSMEs as a critical readiness issue. In Indonesia, some MSMEs implement GenAI only in basic activities such as digital marketing and content creation, rather than integrating it into their operational systems to sustain productivity (Purnomo et al., 2024). Without organizational capability and digital readiness, technological adoption alone cannot improve business productivity.

Several researchers have studied AI adoption, digital transformation, and technology acceptance among SMEs. Arroyabe et al. (2024), for instance, emphasized that digital capability and innovation significantly influence AI adoption among European SMEs. Arroyabe et al. (2024) found digital capabilities and innovation capabilities to be important for AI adoption in SMEs, while Badghish & Soomro used TOE to explain AI adoption and sustainable performance. In comparison, Maroufkhani et al. (2023) highlighted the importance of organizational and technological factors in the implementation of digital technology. In the Indonesian context, Lupiyoadi et al. (2025) revealed that perceived intelligence and performance expectations are important determinants of AI adoption among MSMEs and startups. According to Himmati et al. (2025), the adoption of GenAI by MSMEs needs to be supported by equal distribution of digital infrastructure.

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A research gap emerges because studies on AI adoption in SMEs have primarily focused on technology acceptance, adoption intention, and digital transformation, rather than on how the intensity of GenAI adoption influences MSME productivity (Maroufkhani et al., 2023; Arroyabe et al., 2024). In developing countries such as Indonesia, evidence on GenAI's influence on productivity remains limited, despite its ability to improve knowledge-task and service-work performance (Noy & Zhang, 2023; Brynjolfsson et al., 2025). Only a few studies have integrated technological readiness, organizational support, and organizational readiness into a single AI-enabled productivity framework (Raisch & Krakowski, 2021). To address this research gap, this study examines the intensity of GenAI adoption and MSME productivity in developing countries, focusing on MSMEs in Indonesia.

This study integrates technology adoption theory, the technology-organization-environment (TOE) framework, and the resource-based view to explain how GenAI adoption influences MSME productivity in Indonesia. Unlike previous studies that mainly focused on technology acceptance behavior, this study specifically investigates the role of GenAI adoption intensity and organizational readiness in improving MSME productivity. The literature is not fully unanimous: some studies emphasize perceived usefulness and performance expectancy, while others emphasize readiness, digital capability, TOE factors, managerial support, and implementation maturity. At the same time, this study examines whether the intensity of GenAI use is truly related to productivity outcomes in Indonesian MSMEs.

This study focuses on Indonesia's digital economic transformation and the increasing adoption of AI technologies among MSMEs. MSMEs are expected to adopt digital technologies and transform this adoption into measurable productivity improvement and sustainable business performance. Policymakers, business practitioners, and MSME support institutions should consider both GenAI adoption and productivity outcomes in designing effective AI capability-building strategies, digital literacy programs, and organizational development policies.

This study aims to examine: (1) the effects of perceived usefulness, technological readiness, and organizational support on GenAI adoption intensity; (2) the effect of GenAI adoption intensity on MSME productivity; (3) the direct effects of perceived usefulness, technological readiness, and organizational support on MSME productivity; and (4) the moderating role of organizational readiness in the relationship between GenAI adoption intensity and MSME productivity. The findings are expected to contribute to the literature on AI-driven digital transformation and provide practical implications for strengthening MSME competitiveness within Indonesia's digital economy.

This study integrates UTAUT, TOE, and capability-based perspectives to explain GenAI's shift from experimentation to business value. UTAUT emphasizes perceived performance benefits, TOE highlights technological and organizational readiness, while capability views show that routines and support systems convert technology into productivity (Venkatesh & Thong, 2016). For Indonesian MSMEs, adoption depends on value and readiness, whereas productivity requires operational embedding and governance (Arroyabe et al., 2024; Lupiyoadi et al., 2025).

Perceived usefulness reflects MSME decision makers' belief that GenAI improves performance, efficiency, speed, and decision quality. Technology acceptance theory suggests firms intensify use when technology offers tangible value, especially SMEs facing resource constraints and seeking productivity gains (Maroufkhani et al., 2023; Firdaus, 2026). In Indonesia, performance expectations encourage the use of GenAI for content, service, analysis, and administration (Lupiyoadi et al., 2025).

Organizational support reflects MSME leaders' commitment, encouragement, policy direction, and training that legitimize the use of GenAI in daily operations. AI value depends on balancing automation with human augmentation, while SME adoption is shaped by digital and organizational capabilities (Raisch & Krakowski, 2021). Thus, support signals GenAI as a strategic capability, reduces uncertainty, and encourages adoption in decision-making, customer interaction, and operational learning (Badghish & S., 2024; Oldemeyer et al., 2025). GenAI adoption intensity reflects the breadth, frequency, and routinization of GenAI use across MSME processes, including content creation, customer service, information synthesis, administration, and data-based decisions (Noy & Zhang, 2023). Evidence shows that GenAI improves productivity and quality in knowledge tasks and structured service work (Brynjolfsson et al., 2025). Thus, GenAI supports MSME productivity when embedded in recurring, repetitive, information-intensive, and customer-facing workflows across core operations (Gao & Feng, 2023).

Perceived usefulness strengthens MSME productivity by helping owner-managers recognize, prioritize, and operationalize GenAI in economically meaningful tasks (Rajaram & Tinguely, 2024; Lupiyoadi et al., 2025). When firms identify concrete use cases, GenAI supports task-technology alignment, resource allocation, and workflow redesign. Therefore, decision-makers who perceive GenAI as improving speed, efficiency, and decision quality are more likely to deploy it to achieve measurable productivity gains (Maroufkhani et al., 2023). Technological readiness improves MSME productivity because digital infrastructure, system compatibility, skills, and technical confidence help firms extract value from GenAI after adoption (Arroyabe et al., 2024). In AI-driven contexts, readiness reduces implementation friction, improves experimentation, and stabilizes AI-assisted work. Readiness is not only an adoption precondition but a productivity-enabling capability that converts GenAI into time savings, process efficiency, and higher-quality outputs (Oldemeyer et al., 2025; Calvino et al., 2025).

Organizational support contributes to MSME productivity through managerial commitment, guidance, training, and policy clarity that coordinate the use of GenAI within firms. AI value emerges when organizations design complementary human–machine roles, while supportive organizational conditions help translate AI adoption into sustainable performance (Raisch & Krakowski, 2021; Badghish & Soomro, 2024). Although GenAI can be used informally, productivity gains require routines, usage standards, and continuous learning, transforming experimentation into coordinated practice that strengthens efficiency, reliability, and competitiveness (Oldemeyer et al., 2025; Wahab & Radmehr, 2024).

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Organizational readiness, as a moderating mechanism, is a higher-order capability that combines technological readiness and organizational support, reflecting MSMEs' ability to integrate, govern, and scale the use of GenAI (Arroyabe et al., 2024; Oldemeyer et al., 2025). As a complementarity mechanism, readiness strengthens productivity when infrastructure, skills, governance, and learning routines support adoption. AI produces stronger SME growth when combined with digital assets and organizational mechanisms that transform assimilation into business performance (Ardito et al., 2025).

This study aims to examine how perceived usefulness, technological readiness, and organizational support influence the intensity of generative artificial intelligence adoption among Indonesian micro, small, and medium enterprises. It also evaluates whether adoption intensity improves enterprise productivity and whether organizational readiness strengthens the relationship between generative artificial intelligence adoption and productivity. By addressing these objectives, this study provides empirical evidence on how the adoption of artificial intelligence can support productivity improvements and digital economic transformation in developing economies.

METHODS

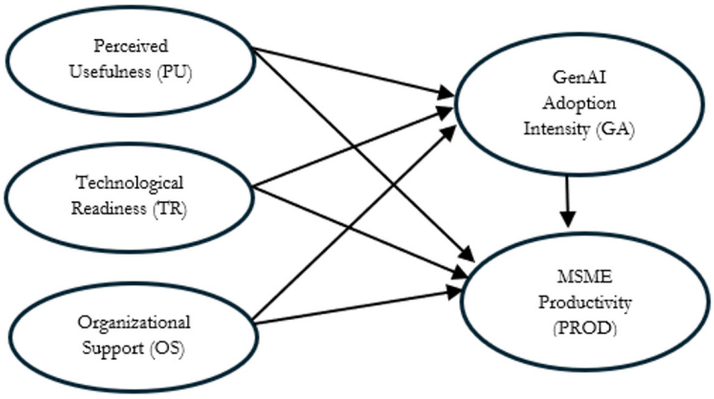
This study employed a quantitative explanatory design, using cross-sectional survey data to examine how perceived usefulness, technological readiness, organizational support, and GenAI adoption intensity explain MSME productivity in Indonesia, consistent with recent research on SME digital transformation and AI adoption (Anatan & Nur, 2023; Arroyabe et al., 2024). The unit of analysis was the MSME firm. In contrast, the unit of response was the owner, manager, or senior decision-maker because these actors usually understand technology adoption, workflow change, and productivity consequences in small firms (Badghish & Soomro, 2024; Lupiyoadi et al., 2025).

Respondents were selected through purposive sampling with three criteria: the firm operated as an Indonesian MSME, the respondent was involved in business decision-making, and the firm had used or evaluated GenAI tools for business activities (Oldemeyer et al., 2025). Respondents were owners/managers/senior decision-makers of Indonesian MSMEs who had used or evaluated GenAI for business activities. After screening 203 returned questionnaires, three observations were excluded because they did not meet the MSME criterion, resulting in a final sample of 200 firms, which is adequate for prediction-oriented PLS-SEM with several latent constructs and structural paths, particularly for sample size, measurement model, and structural model (Hair et al., 2019; Laroibafih, 2025; Firdaus, 2026).

All constructs were measured reflectively using a five-point Likert scale from 1 = strongly disagree to 5 = strongly agree, following recent studies that treated technology perceptions, readiness, organizational support, adoption, and productivity as latent managerial constructs (Maroufkhani et al., 2023; Wahab & Radmehr, 2024). The research framework integrates technology acceptance, technology–organization–environment, and capability-based perspectives by modeling perceived usefulness, technological readiness,

and organizational support as antecedents of GenAI adoption intensity and MSME productivity (Arroyabe et al., 2024; Lupiyoadi et al., 2025). Operational definitions of variables are presented in Table 1.

Figure of the conceptual model



Source: Data processed using SEM PLS, 2026

Table 1. Operational Definitions of Variables

Construct	Operational definition	Indicators
Perceived Usefulness (PU)	Belief that GenAI improves performance and efficiency.	PU1–PU4
Technological Readiness (TR)	Availability of infrastructure, compatibility, and digital skills for GenAI.	TR1–TR4
Organizational Support (OS)	Leadership commitment, policies, encouragement, and training for GenAI.	OS1–OS4
GenAI Adoption Intensity (GA)	Breadth and routinization of GenAI use across business processes.	GAI1–GAI4
MSME Productivity (PROD)	Perceived improvement in output and efficiency attributable to GenAI use.	PROD1–PROD4

Source: Adapted from prior validated scales and the present survey instrument

Organizational readiness was specified as a higher-order capability combining technological readiness and organizational support, because AI productivity depends on complementary infrastructure, skills, managerial support, and workflow integration (Badghish & Soomro, 2024; Calvino et al., 2025).

The empirical structural equations were specified as follows:

$GA = \beta_0 + \beta_1 PU + \beta_2 TR + \beta_3 OS + \varepsilon$ and

$PROD = \alpha_0 + \alpha_1 PU + \alpha_2 TR + \alpha_3 OS + \alpha_4 GA + \alpha_5 (GA \times OR) + \xi$

The reflective measurement model was expressed as $x_{ij} = \lambda_j \eta_i + \delta_{ij}$

where x_{ij} represents each observed indicator, λ_j is the indicator loading, η_i is the latent construct, and δ_{ij} is measurement error (Hair et al., 2019).

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Convergent validity was evaluated using indicator loadings, Cronbach's alpha, composite reliability, and average variance extracted, with $AVE = \Sigma\lambda^2/n$ and $CR = (\Sigma\lambda)^2/[(\Sigma\lambda)^2 + \Sigma(1 - \lambda^2)]$. The structural model was estimated using SmartPLS 4 with a PLS algorithm and bootstrapping to assess path coefficients, *t*-values, *p*-values, R^2, f^2, and the moderation effect of organizational readiness (Hair et al., 2019). The study used cross-sectional and self-reported data; all relationships were interpreted as associative rather than strictly causal, while future studies are encouraged to apply longitudinal designs and objective productivity indicators (Calvino et al., 2025; Permana, 2026).

RESULT AND DISCUSSION

After excluding three non-MSME observations (large firms), the final sample comprises 200 Indonesian MSMEs, dominated by trade (n=109) and services (n=42), followed by manufacturing/industry (n=16) and information technology (n=13) (Survey data, 2026). The sample includes micro (n=68), small (n=80), and medium-sized firms (n=52), reflecting heterogeneous MSME conditions within Indonesia's digital transformation context and providing a balanced empirical basis for examining GenAI adoption across enterprise scales nationally (Anatan & Nur, 2023). All indicator loadings exceed 0.70 except TR3 (0.709), which remains acceptable for exploratory work. Composite reliability ranges from 0.886 to 0.920 and AVE from 0.661 to 0.742, as shown in Table 2, supporting convergent validity (Hair et al., 2019; Laroibafih, 2025).

Table 2. Indicator Loadings (Outer Model)

Construct	Item	Loading	Information
PU	PU1	0.853	Valid
PU	PU2	0.841	Valid
PU	PU3	0.847	Valid
PU	PU4	0.898	Valid
TR	TR1	0.852	Valid
TR	TR2	0.833	Valid
TR	TR3	0.709	Valid
TR	TR4	0.848	Valid
OS	OS1	0.848	Valid
OS	OS2	0.873	Valid
OS	OS3	0.851	Valid
OS	OS4	0.812	Valid
GA	GAI1	0.834	Valid
GA	GAI2	0.837	Valid
GA	GAI3	0.907	Valid
GA	GAI4	0.866	Valid
PROD	PROD1	0.878	Valid
PROD	PROD2	0.834	Valid
PROD	PROD3	0.862	Valid
PROD	PROD4	0.837	Valid

Findings suggest that Indonesian MSMEs must not only adopt GenAI but also build capabilities to convert adoption into sustained performance. GenAI productivity depends on task features, worker expertise, and organizational adaptation, while SME AI implementation is constrained by capability gaps, governance issues, and immaturity (Calvino et al., 2025). Indonesia's MSME digital transformation should prioritize capability-building beyond technology access (Purnomo et al., 2024). Government, universities, and support institutions should strengthen AI literacy, workflow integration, and digital governance so GenAI becomes a productivity engine rather than an experimental tool (Murniati et al., 2021; Rajaram & Tinguely, 2024).

Table 3. Descriptive Statistics of Latent Constructs

Construct	Mean	Standard Deviation (SD)
PU	4.182	0.846
TR	4.003	0.850
OS	3.937	0.908
GA	3.834	0.961
PROD	4.072	0.840

Source: Survey data (n=200)

Table 3 presents descriptive statistics of the latent constructs and shows that perceived usefulness has the highest mean, followed by productivity, technological readiness, organizational support, and GenAI adoption intensity (Rajaram & Tinguely, 2024). This indicates that Indonesian MSMEs already perceive GenAI as relevant and beneficial, although routinization and workflow integration remain less mature. Thus, MSMEs may recognize GenAI's promise before developing routines, skills, and governance needed for systematic productivity gains (Oldemeyer et al., 2025; Calvino et al., 2025).

The measurement model shows adequate reliability and convergent validity for analyzing GenAI adoption and MSME productivity in a future-oriented digital business context. Most indicator loadings exceed 0.70, composite reliability ranges from 0.886 to 0.920, and AVE ranges from 0.661 to 0.742, meeting PLS-SEM criteria, as shown in Table 4 (Hair et al., 2019). TR3 is considered acceptable because construct reliability and AVE are satisfactory, though they are near the recommended threshold.

Table 4. Construct Reliability and Convergent Validity

Construct	Cronbach's α	Composite reliability	AVE
PU	0.882	0.919	0.740
TR	0.827	0.886	0.661
OS	0.868	0.910	0.716
GA	0.882	0.920	0.742
PROD	0.873	0.914	0.728

Source: Data processed using SEM PLS, 2026

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Table 5. Discriminant Validity: Fornell–Larcker Criteria

Construct	PU	TR	OS	GA	PROD
PU	0.860	0.719	0.725	0.653	0.832
TR	0.719	0.813	0.750	0.685	0.712
OS	0.725	0.750	0.846	0.642	0.758
GA	0.653	0.685	0.642	0.861	0.657
PROD	0.832	0.712	0.758	0.657	0.853

Source: Data processed using SEM PLS, 2026

Table 5 shows that each construct shares greater variance with its indicators than with other constructs, supporting discriminant validity among perceived usefulness, technological readiness, organizational support, GenAI adoption intensity, and MSME productivity (Hair et al., 2019). However, the close link between perceived usefulness and productivity suggests future studies should refine items and include objective indicators, such as output per worker, sales per employee, transaction speed, or error reduction (Hair et al., 2019). Table 6 indicates moderate-to-substantial explanatory power: adoption is driven by usefulness and readiness, while productivity is strengthened by usefulness, support, routines, and AI-enabled workflows (Arroyabe et al., 2024; Oldemeyer et al., 2025).

Table 6. Effect Sizes (f^2)

Endogenous construct	R^2
GA	0.534
PROD	0.751

Source: Data processed using SEM PLS, 2026

Table 6 shows that the proposed model explains 53.4% of the variance in GenAI adoption intensity (R^2 = 0.534) and 75.1% of the variance in MSME productivity (R^2 = 0.751), indicating moderate and substantial explanatory power (Hair et al., 2019). The adoption result suggests that AI-enabled routines are influenced by readiness and perception, while the productivity result shows that the model captures key mechanisms of future business performance. Robust measurement quality and conceptual clarity further support the interpretation of GenAI as a strategic productivity engine for MSMEs.

This section reports the f^2 effect sizes, indicating each predictor's practical contribution to GenAI adoption intensity and MSME productivity (Hair et al., 2019). Perceived usefulness has the strongest effect on productivity (f^2 = 0.432), showing that GenAI creates greater value when firms recognize its relevance for efficiency, decision-making, and operational improvement (Rajaram & Tinguely, 2024). Technological readiness contributes most to adoption intensity (f^2 = 0.104), while organizational support also strengthens productivity (f^2=0.096), confirming the importance of infrastructure, digital skills, and

managerial guidance (Arroyabe et al., 2024; Oldemeyer et al., 2025). Weaker effects of PU on adoption, OS on adoption, GA on productivity, and TR on productivity suggest that GenAI use requires organizational capabilities and workflow integration (Hair *et al.*, 2019).

Table 7. Extended Model: Readiness and Complementarity Test

Predictor	Endogenous	f^2
PU	GA	0.060
TR	GA	0.104
OS	GA	0.026
PU	PROD	0.432
TR	PROD	0.007
OS	PROD	0.096
GA	PROD	0.017

Source: Data processed using SEM PLS, 2026

Table 8. Hypothesis Testing Results

Hypothesis	Path	B	Standard Error (SE)	*t*-value	*p*-value	Sig.
H1	PU → GA	0.263	0.110	2.393	0.018	0.018
H2	TR → GA	0.360	0.149	2.410	0.017	0.017
H3	OS → GA	0.181	0.116	1.570	0.118	0.118
H4	GA → PROD	0.095	0.062	1.538	0.126	0.126
H5	PU → PROD	0.531	0.084	6.296	0.000	0.000
H6	TR → PROD	0.071	0.082	0.860	0.391	0.391
H7	OS → PROD	0.259	0.076	3.389	0.001	0.001
H8	GA × OR →PROD	-0.039	0.059	-0.664	0.507	0.507

Source: Data processed using SEM PLS, 2026

This study shows that GenAI adoption intensity in Indonesian MSMEs is driven by perceived usefulness and technological readiness, whereas productivity depends on perceived usefulness and organizational support, rather than on adoption intensity alone (see Table 8). GenAI creates value when decision makers understand its benefits and firms provide guidance, training, and workflow support (Rajaram & Tinguely, 2024). The insignificant adoption–productivity effect suggests frequent use becomes productive only when embedded in structured tasks, human AI collaboration, and routines (Noy & Zhang, 2023). Organizational readiness is an enabler, not a moderator (Arroyabe et al., 2024).

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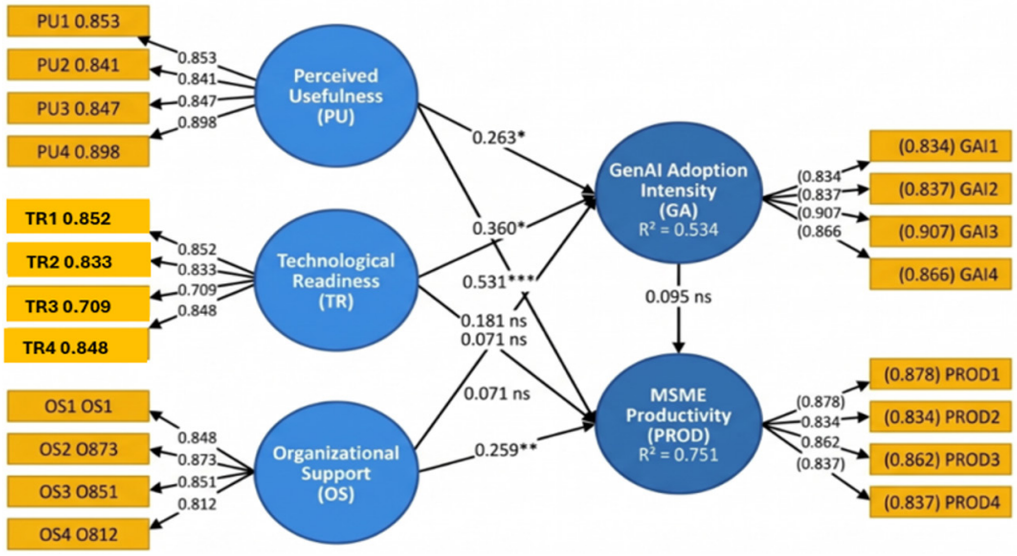
Figure 2. Structure and Measurement Model Result



Source: Data processed using SEM PLS (2026)

The extended model, as shown in Table 8, shows that organizational readiness, combining technological readiness and organizational support, significantly improves GenAI adoption intensity (β = 0.507; p = 0.000) and MSME productivity (β = 0.296; p = 0.000), but does not moderate the adoption–productivity relationship (Hair et al., 2019; Arroyabe et al., 2024). The findings imply that public policy should prioritize AI capability-building, digital literacy, and institutional support to strengthen MSME productivity and competitiveness in Indonesia's digital economy (Oldemeyer et al., 2025; Purnomo et al., 2024).

The data analysis found that perceived usefulness and technological readiness drive the intensity of GenAI adoption. MSMEs will use GenAI more routinely if the business benefits are clear and the infrastructure/skills are adequate. The next finding is that productivity is more influenced by perceived usefulness and organizational support, not adoption intensity alone, but according to workflow integration needs. The third finding is that organizational readiness is better understood as a direct enabling capability rather than a moderator. Moreover, the final finding of insignificant results is not a weakness but a theoretical insight that easily accessible GenAI does not automatically increase productivity without governance, SOPs, training, and task redesign.

Determinants of GenAI adoption intensity among Indonesian MSMEs show that perceived usefulness and technological readiness significantly increase adoption intensity, whereas organizational support has no direct effect in the baseline model (Lupiyoadi et al., 2025). Perceived usefulness encourages MSMEs to intensify GenAI use when the technology is seen as improving efficiency, speed, and decision quality, consistent with evidence that performance beliefs and perceived intelligence drive AI adoption in Indonesian MSMEs and startups. GenAI is also adopted more actively when linked

to concrete business use cases (Rajaram & Tinguely, 2024). Technological readiness, including infrastructure, compatibility, and digital skills, reduces experimentation costs and supports routine integration into workflows and operational decisions (Arroyabe et al., 2024; Oldemeyer et al., 2025)

Organizational support, by contrast, does not significantly affect the intensity of GenAI adoption in the baseline model. Badghish & Soomro (2024) reported that organizational factors can support AI adoption and sustainable business performance in SMEs, while Oldemeyer et al. (2025) emphasized that management support and internal capability development remain important for overcoming implementation challenges. The present result may reflect the distinctive reality of Indonesian MSMEs, where GenAI can be tried informally through accessible applications before formal policies, structured training, or managerial governance are established. As Raisch & Krakowski (2021) suggested, the managerial challenge of AI lies in balancing automation and augmentation, which means that organizational support may become more decisive after firms move from experimentation toward coordinated value capture.

The second research question investigates whether the intensity of GenAI adoption and readiness-related variables improve MSME productivity. The results indicate that perceived usefulness and organizational support have significant positive effects on productivity, whereas technological readiness and GenAI adoption intensity do not have statistically significant direct effects. Rajaram & Tinguely (2024) argued that GenAI creates value in SMEs when firms identify high-frequency use cases and align the technology with concrete operational needs, while Calvino et al. (2025) emphasized that GenAI productivity gains depend on task fit, user capability, and human-AI collaboration. Thus, usefulness matters because it shapes the quality, purpose, and strategic direction of AI use, allowing MSMEs to move from simple tool adoption toward future-ready value creation. Technological readiness does not directly improve productivity, meaning infrastructure and digital skills alone are insufficient for performance gains (Wahab & Radmehr, 2024). It becomes productive only through complementary mechanisms such as absorptive capacity, customer agility, IoT, big data analytics, routines, data-informed processes, complementary investments, and adaptive organizational learning (Ardito et al., 2025).

Organizational support has a significant positive effect on MSME productivity, indicating that managerial commitment, internal guidance, encouragement, and training are crucial for transforming GenAI into reliable business outcomes. Badghish and Soomro (2024) highlighted that organizational conditions are important for converting AI adoption into sustainable business performance, while Oldemeyer et al. (2025) showed that SMEs often struggle not only with technical readiness, but also with managerial coordination, governance, and workforce preparation. These results suggest that GenAI may be easy to access but harder to monetize effectively unless firms build supportive routines, learning cultures, and clear standards for AI-assisted work.

The direct effect of GenAI adoption intensity on productivity is positive but not statistically significant, indicating that more frequent GenAI use does not automatically

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lead to firm-level productivity gains among Indonesian MSMEs. According to Noy and Zhang (2023), GenAI can improve productivity and output quality in professional writing tasks, while Brynjolfsson et al. (2025) reported substantial productivity improvements among customer-support workers using GenAI assistance. The different result in this study is substantively meaningful because MSMEs often use GenAI across heterogeneous, less structured, and still-emerging business activities. As Calvino et al. (2025) argued, the productivity effect of GenAI depends on how the technology is embedded into tasks, human expertise, and organizational adaptation, not merely on the intensity of use.

Organizational readiness and complementarity mechanisms show that organizational readiness, shaped by technological readiness and organizational support, positively affects GenAI adoption intensity and productivity, confirming its role in translating experimentation into business value (Arroyabe et al., 2024; Oldemeyer et al., 2025). However, the insignificant adoption–readiness interaction, as shown in Table 8, indicates no moderating effect, suggesting that Indonesian MSMEs lack the maturity to become productivity multipliers (Wahab & Radmehr, 2024). GenAI use remains focused on simple tasks, so complementarity may emerge once stronger routines, governance, data discipline, and learning mechanisms are in place (Anatan & Nur, 2023).

Taken together, the findings indicate that the main challenge for Indonesian MSMEs is not simply to adopt GenAI, but to develop the internal capabilities required to convert adoption into sustained business performance. Calvino emphasized that GenAI productivity depends on task characteristics, worker expertise, and organizational adaptation, while Oldemeyer et al. (2025) showed that capability gaps, governance issues, and limited implementation maturity constrain SME AI implementation.

The findings imply that Indonesia's MSME digital transformation agenda should move beyond access to technology and emphasize capability-building policies (Purnomo et al., 2024). Government agencies, universities, and MSME support institutions should provide AI literacy programs, workflow integration training, and digital governance support to ensure that GenAI adoption produces measurable productivity gains. From a future-oriented economic development perspective, this study shows that AI-based MSME upgrading is not merely a technology diffusion agenda (Murniati et al., 2021), as emphasized by Rajaram & Tinguely (2024). Rather, it is a capability-building journey in which usefulness, readiness, support, and strategic integration determine whether GenAI becomes a productivity engine or remains an experimental tool. This study has several limitations. First, the data are cross-sectional and rely on self-reported productivity measures. Second, the sample focuses on Indonesian MSMEs and may not fully represent other developing economies.

CONCLUSION

This study examined how perceived usefulness, technological readiness, organizational support, GenAI adoption intensity, and organizational readiness explain MSME productivity in Indonesia's digital economy. The findings address the research objectives by showing

that perceived usefulness and technological readiness significantly increase the intensity of GenAI adoption, whereas organizational support does not directly affect adoption intensity. Regarding productivity, perceived usefulness and organizational support have significant positive effects, whereas technological readiness and GenAI adoption intensity do not directly improve it. Organizational readiness functions more as a direct enabling capability than as a moderator of the adoption–productivity relationship. These results indicate that GenAI adoption alone is insufficient to produce measurable productivity gains unless MSMEs integrate AI into workflows, improve employee skills, and receive managerial support. Policy should prioritize AI literacy training, workflow-integration assistance, digital infrastructure support, and practical guidelines for responsible GenAI use. Future research should employ longitudinal designs, objective productivity indicators such as sales per employee, transaction speed, error reduction, or output per worker, and comparative cross-country analysis to strengthen causal interpretation.

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What Drives Investors in Fintech Lending? Firm-Level Evidence from Indonesian Platforms

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ABSTRACT

Research Originality: This study offers a novel firm-level perspective on fintech lending by examining platform characteristics, addressing a gap in the literature that has predominantly focused on campaign-level or aggregate data, and extending signaling theory to fintech contexts.

Research Objectives: The study aims to investigate the determinants of investor participation in fintech lending platforms in Indonesia, focusing on platform age, outstanding loan volume, Shariah compliance, and platform scope.

Research Methods: The analysis uses cross-sectional data from 85 licensed fintech lending platforms and applies multiple regression with robust standard errors, controlling for financial performance (ROA, ROE), firm size (assets), and default risk (TWP90).

Empirical Results: The findings indicate that platform age, lending scale, and Shariah compliance positively and significantly influence investor participation, whereas platform scope does not.

Implications: The study highlights the importance of credibility, scale, and ethical positioning in attracting investors. It provides insights for platform operators to strengthen trust and for regulators to enhance transparency and stability, supporting the development of a sustainable fintech lending ecosystem.

Keywords:
fintech lending; investor participation; platform characteristics; shariah compliance; signaling theory

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INTRODUCTION

The rapid expansion of financial technology (fintech) has transformed traditional financial intermediation, with fintech lending platforms emerging as one of the most disruptive innovations in recent years (Cai, 2018). By directly connecting borrowers and lenders through digital infrastructure, fintech lending reduces transaction costs (Hughes et al., 2022), enhances financial inclusion (Ha et al., 2025), and provides alternative investment opportunities outside conventional banking systems (Hodula, 2022). In emerging economies such as Indonesia, where access to formal financial services remains uneven, fintech lending platforms play a particularly important role in bridging financial gaps for underserved individuals and small and medium-sized enterprises (SMEs). As bank-based financial systems continue to dominate, fintech lending offers a complementary channel that expands credit access while also creating new avenues for retail and institutional investors (Jagtiani & Lemieux, 2018).

In the Indonesian context, the growth of fintech lending platforms has been particularly remarkable over the past decade, both in terms of market size and regulatory development. The industry continues to expand rapidly, as evidenced by the latest Monthly Statistical Report of the Financial Services Authority (OJK), which shows that total outstanding digital loans increased from IDR 72.03 trillion in August 2024 to IDR 87.49 trillion in August 2025 (OJK, 2025), representing an annual growth rate of approximately 21.5%. This rate significantly outpaces the growth of traditional bank lending, which stands at only around 6.9%, highlighting the increasingly important role of fintech lending platforms in Indonesia's credit market. In parallel, the number of licensed platforms has become more consolidated and regulated, with 96 fintech lending platforms officially registered and licensed by OJK, reflecting a transition from rapid expansion to a more mature and supervised industry structure.

Regulatory frameworks have also evolved to enhance transparency and investor protection, most notably through the issuance of POJK No. 77/POJK.01/2016, which was later updated by POJK No. 10/POJK.05/20222, concerning information technology-based lending services. These regulations establish licensing requirements, governance standards, risk management protocols, and disclosure obligations for fintech lending platforms. Despite industry advancements and regulatory reforms, challenges remain, including elevated default rates in certain segments, significant platform heterogeneity, and the persistence of illegal or unregistered operators. These dynamics underscore the importance of understanding the characteristics of fintech lending platforms and how this affects investor participation, as investor confidence is fundamental to sustaining industry growth and long-term stability.

Existing literature on fintech lending has predominantly focused on project- or campaign-level information available on platforms (e.g., Chen et al., 2020; Jiang et al., 2018; Lee & Lee, 2012), as well as aggregate-level fintech data (e.g., Cornelli et al., 2023; Jiang et al., 2018), in explaining funding outcomes and investor behavior. While these approaches provide important insight into micro-level decision-making and overall market trends, relatively limited attention has been devoted to understanding the firm-

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level characteristics of fintech lending platforms themselves as key determinants of investor participation. This gap is particularly salient in the Indonesian context, where platform heterogeneity is substantial, spanning newly established firms, more mature platforms, and both conventional and shariah-compliant models. Moreover, prior studies tend to rely heavily on evidence from developed markets such as the United States and China (e.g., Gao, 2022; Sheng, 2021), thereby constraining their relevance for emerging economies characterized by distinct institutional settings, regulatory frameworks, and socio-cultural dynamics (Claessens et al., 2018).

A growing body of literature on fintech lending shows that information asymmetry, borrower characteristics, and platform-mediated signals largely drive investor behavior and funding outcomes. Early studies emphasize the role of both hard information (e.g., credit scores and loan terms) and soft information (e.g., narrative and social networks) in shaping funding success and interest rates (e.g., Ge et al., 2017; Iyer et al., 2016; Rama et al., 2022), alongside herding dynamics among investors (e.g., Herzenstein et al., 2011; Lee & Lee, 2012). A systematic review by Basha et al. (2021) confirms that most studies focus on loan-level determinants with strong predictive power for funding and default outcomes. More recent research incorporates broader factors such as uncertainty, macroeconomic conditions, and user perceptions – highlighting the importance of trust, transparency, and expected returns in influencing investor decisions (Del Sarto, 2024; Foo et al., 2017; Hettler et al., 2025). From a regulatory perspective, weak governance and excessive competition have also been linked to systematic risk in fintech lending markets (Gu et al., 2026). Despite these advances, literature remains heavily concentrated on loan-level analysis, with limited attention to firm-level characteristics of platforms as signals of credibility and risk, particularly in emerging markets.

Addressing this gap, the present study shifts the analytical focus from loan-level to firm-level determinants of investor participation in fintech lending platforms in Indonesia. Specifically, it examines how platform characteristics – namely, firm age, outstanding loan volume, shariah compliance, and platform scope (domestic versus international) – influence investors' decisions to allocate funds. This approach is grounded in signaling theory (Spence, 1973), which posits that investors rely on observable firm attributes to infer platform quality and credibility in environments characterized by information asymmetry (Rama et al., 2026). For example, older platforms may signal greater stability and experience, while outstanding loan portfolios may indicate stronger market acceptance and operational capacity. Shariah compliance introduces an additional layer of ethical and religious alignment, potentially shaping investor preferences in a predominantly Muslim context. In contrast, platform scope reflects market reach and diversification opportunities relevant for risk management. Collectively, these factors provide a more comprehensive framework for understanding investor behavior beyond traditional loan-level analysis.

Against this backdrop, this study addresses the central research question: what factors drive investor participation in fintech lending platforms in Indonesia? More specifically, it examines how firm age, outstanding loan volume, shariah compliance, and platform scope (domestic vs. international) influence investor decisions.

This study offers several theoretical implications. *First*, it extends signaling theory by demonstrating how firm-level attributes of digital platforms function as credibility signals in fintech markets characterized by high uncertainty and limited transparency. While prior studies have applied signaling theory primarily to borrower characteristics (e.g., Ge et al., 2017; Iyer et al., 2016), this study broadens its application to platform-level analysis, thereby enriching the theoretical framework. *Second*, the study contributes to the literature on financial intermediation by highlighting the evolving role of fintech platforms as hybrid intermediaries that combine technological infrastructure with reputational capital (e.g., Oseni & Ali, 2019; Rama & Yaman, 2025). *Third*, by incorporating shariah compliance into analysis, the study integrates insights from Islamic finance into mainstream fintech research (Sidaoui et al., 2022), offering a more inclusive theoretical perspective that accounts for value-based investment behavior. *Finally*, the findings are expected to inform policymakers and platform operators regarding the key drivers of investor confidence, thereby supporting the development of a more robust and sustainable fintech lending ecosystem in Indonesia.

METHODS

This study employs a quantitative approach using multiple regression analysis to examine the determinants of investor participation in fintech lending platforms in Indonesia. Given the cross-sectional nature of firm-level data and the potential presence of heteroskedasticity, the model is estimated using ordinary least squares (OLS) with robust standard errors to ensure reliable statistical inference. The baseline empirical model is specified as follows:

$$InvestorParticipation_i = \alpha_0 + \beta_1 PlatformAge_i + \beta_2 OutstandingLoan_i + \beta_3 ShariahPlatform_i + \beta_4 PlatformScope_i + \beta_5 X_i + \varepsilon_i$$

where i denotes the fintech lending platform, and X_i represents a vector of control variables including firm size, profitability (ROA and ROE), and risk indicators. The dependent variable, *Investor participation*, is measured as the natural logarithm of total investor participation to reduce skewness and capture proportional effects. The key independent variables include platform age, outstanding loans, shariah-compliant platform, and platform scope, while the control variables account for financial characteristics that may influence investor decisions.

The inclusion of the developed variables is grounded in signaling theory, where observable firm-level characteristics serve as signals of platform credibility, performance, and risk in the presence of information asymmetry. For instance, older platforms and those with larger loan portfolios may signal stability and market acceptance, while shariah compliance and platform scope may capture investor preference and perceived legitimacy. Table 1 summarizes the definition and measurement of all variables used in the analysis.

The sample of this study consists of 85 fintech lending platforms operating in Indonesia, selected from a total population of 95 platforms that have been officially licensed by the Financial Services Authority (OJK). The final sample is determined based on data availability and completeness of required variables.

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Table 1. Variable Definition and Measurement

Variable	Definition	Measurement
Investor participation	Level of investor involvement in the platform (P2P lending firm)	Natural log of total investor participation
Platform age	Age of the fintech lending platform (P2P lending firm)	Number of years since establishment
Outstanding loan	Total value of loans currently outstanding	Natural log of total outstanding loans (IDR)
Shariah-compliant platform	Indicator for shariah-compliant platform	1 = Shariah, 0 = Conventional
Platform scope	Geographic scope of platform operators	1 = National, 0 = International
Asset	Firm size measured by total assets	Natural log of total assets (IDR)
ROA	Profitability based on assets	Net income / total assets
ROE	Profitability based on equity	Net income / total equity
Default risk	Credit risk measured by 90-day delinquency rate	Percentage of loans overdue > 90 days

All data used in this study are manually collected from the official websites of each fintech lending platform in August 2025. This manual data collection approach allows for the construction of a unique firm-level dataset, particularly for variables that are not readily available in standardized financial databases, such as platform characteristics (e.g., shariah compliance and platform scope) and investor participation indicators. Financial variables, including total assets, profitability measures (ROA and ROE), and default risk, are obtained from publicly disclosed reports and platform disclosures.

The use of firm-level data is a key contribution of this study, as it enables a more comprehensive analysis of platform characteristics than prior research that predominantly relies on loan-level or aggregate data. By focusing on platform-level heterogeneity, this study provides deeper insight into the structural and financial factors that influence investor participation in fintech lending markets.

RESULTS AND DISCUSSION

Table 2 presents the descriptive statistics of the variables used in this study, based on a sample of 85 licensed fintech lending platforms in Indonesia. The average level of investor participation is relatively high at 20,450 investors. However, it exhibits substantial variation, as reflected in a large standard deviation (106,276) and a wide range between the minimum (2) and maximum (886,000). This indicates a highly uneven distribution of investor engagement across platforms, suggesting that a small number of platforms dominate in attracting investors. Similarly, outstanding loan volume exhibits significant dispersion, with a mean of IDR 744,000 million and a maximum of IDR 15,200,000 million, highlighting considerable heterogeneity in platform scale and market activity. In contrast, platform age appears to be more evenly distributed, with an average of

approximately 8 years, indicating that most platforms are relatively mature but still vary in terms of operational experience.

Table 2. Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Investor participation	85	20,450.19	106,276.10	2	886,000
Platform age	85	7.87	2.41	5	25
Outstanding loan (*million IDR*)	85	744,000	1,920,000	1.02	15,200,000
Shariah compliant platform	85	0.07	0.26	0	1
Platform scope	85	0.96	0.19	0	1
Asset (*million IDR*)	85	54,500	132,000	5.99	733,000
ROA	85	-0.10	0.64	-3.76	1.40
ROE	85	0.42	4.03	-35.66	4.13
Default risk	85	0.95	0.13	0.14	1

Regarding platform characteristics, only 7% of the sampled platforms are shariah-compliant, suggesting that the fintech lending industry in Indonesia remains predominantly conventional. Meanwhile, 96% of platforms operate nationally, indicating limited international expansion among Indonesian fintech lenders. In terms of financial characteristics, the average total assets amount to IDR 54,500 million, although with considerable variation, reflecting differences in firm size. Profitability indicators show mixed performance: an average ROA of -0.10 suggests many platforms may still be in a growth or loss-making phase. At the same time, ROE is positive on average (0.42) but highly volatile. Finally, default risk, measured by TWP90, indicates a relatively low level of credit risk, with a mean value of 0.95. Since TWP90 reflects the proportion of loans successfully repaid within 90 days, this implies that approximately 95% of obligations are fulfilled on time, leaving only around 5% as non-performing loans. This level remains within the regulatory threshold set by the OJK, which generally requires that default rates do not exceed 5%. Overall, the descriptive statistics highlight substantial heterogeneity in platform size, performance, and risk, thereby justifying further empirical analysis to examine how these factors influence investor participation.

Table 3. Asset size category and investor participation

Asset size category	Freq.	Percent	Mean (billion IDR)	Range (billion IDR)	Investor participation
Small	29	34.12	2.55	0.01 – 6.23	1,275
Medium	28	32.94	1,410	6.59 – 2,690	544
Large	28	32.94	4,900	2,710 – 73,300	60,216

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Table 3 provides a further descriptive exploration by classifying fintech lending platforms into small, medium, and large based on asset size, using the bottom, middle, and top 33% of the sample distribution. Small platforms, which account for 34.12% of the sample, have an average asset size of IDR 2.55 billion (ranging from IDR 0.01 to 6.23 billion) and attract relatively low investor participation, with an average of 1,275 investors. In contrast, medium-sized platforms (32.94%) exhibit a substantial increase in scale, with average assets of IDR 1,410 billion (range: IDR 6.59 to 2,690 billion). Yet, they record a lower average investor participation of 544, suggesting that asset growth does not linearly translate into broader investor engagement at this stage. Notably, large platforms (32.94%) dominate in both scale and investor participation, with average assets of IDR 4,900 billion (range: IDR 2,710 to 73,300 billion) and a significantly higher average investor participation of 60,216. The pattern suggests a non-linear relationship between firm size and investor participation, where only sufficiently large platforms attract a substantially broader investor base. It reflects scale effects and threshold dynamics, with larger platforms benefiting from greater credibility, visibility, and network advantages.

Table 4. Age Category and Investor Participation

Age category	Freq.	Percent	Mean	Age range	Investor participation
Early	43	50.59	6	5 - 7 years	2,331
Growth	23	27.06	8	8 years	10,417
Mature	19	22.35	11	9 - 25 years	73,604

Table 4 further classifies fintech lending platforms into early, growth, and mature stages based on firm age and examines their association with investor participation. The sample is dominated by early-stage platforms (50.59%) with an average age of 6 years, which attract relatively low investor participation (an average of 2,331 investors). Platforms in the growth stage (27.06%), with an average age of 8 years, show a notable increase in investor participation to 10,417. This upward trend is more pronounced among mature platforms (22.35%) aged 9 to 25 years, which attract substantially higher participation, averaging 73,604 investors. Overall, the results indicate a clear positive relationship between platform maturity and investor participation, suggesting that older platforms benefit from accumulated experience, reputation, and investor trust.

Prior to conducting multiple regression analysis, the study performs correlation and multicollinearity diagnostics. Table 5 presents the pairwise correlation matrix, indicating that the independent variables are not highly correlated with one another, thereby reducing concerns related to multicollinearity and ensuring the reliability of coefficient estimates.

Table 5. Correlation

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Investor participation (1)	1.000								
Platform age (2)	0.463***	1.000							
Outstanding loan (3)	0.279**	0.112	1.000						
Shariah compliant platform (4)	0.169	-0.062	-0.023	1.000					
Platform scope (5)	-0.136	-0.063	-0.032	0.053	1.000				
Asset (6)	0.119	0.184	0.237*	-0.294**	0.139	1.000			
ROA (7)	-0.064	-0.081	0.226*	-0.047	0.173	0.242*	1.000		
ROE (8)	-0.002	-0.077	0.046	0.066	0.027	0.033	0.351**	1.000	
Default risk (9)	-0.138	-0.253*	0.004	0.054	0.357***	0.150	0.220*	0.176	1.000

Note: *, **, and *** indicate statistical significance at the $p < 0.05$, $p < 0.01$, and $p < 0.001$ levels, respectively

Table 6. VIF results

Variable	VIF	1/VIF
Platform age	1.15	0.87
Outstanding loan	1.12	0.89
Shariah compliant platform	1.12	0.89
Platform scope	1.19	0.84
Asset	1.31	0.76
ROA	1.31	0.76
ROE	1.17	0.85
Default risk	1.30	0.77
Mean VIF	1.21	

Furthermore, Table 6 reports the Variance Inflation Factor (VIF) results to formally assess multicollinearity. The findings show that all variables have low VIF values, with an average VIF of 1.21, well below the commonly accepted threshold of 5. This confirms that multicollinearity is not a concern in the model, and the estimated regression results can be interpreted with confidence. Table 7 reports the regression results examining the determinants of investor participation across fintech lending platforms. Columns (1) – (4) present baseline estimations for each main explanatory variable, while column (5) reports the full model. All specifications consistently include control variables – asset size, ROA, ROE, and default risk – to account for firm-level financial characteristics.

Using the full model in column (5) as the primary reference, platform age exhibits a positive effect on investor participation. The finding suggests that more mature platforms tend to attract more investors, likely due to accumulated reputation, operational experience, and greater trust. The finding is consistent with prior literature emphasizing the role of firm maturity in shaping investor behavior. For example, Chakraborty et al. (2023) show that firm characteristics, including age and governance quality, influence investor participation, while Yang and Shyu (2019) highlight the importance of firm life cycle stages. Korniotis and Kumar (2011) suggest that experience and maturity shape

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investment decisions, supporting the argument that more mature platforms tend to attract more investors. Outstanding loans also show a positive effect on investor participation, indicating that platforms with higher lending volumes tend to attract more investors. This reflects the signaling role of platform scale and activity, where larger loan disbursement may indicate stronger demand and platform viability. This finding aligns with existing literature (e.g., Herzenstein et al., 2011; Lee & Lee, 2012; Zhang & Liu, 2012), which highlights that higher transaction volumes serve as positive signals to potential investors.

Table 7. Regression results

Variable	Investor participation				
	(1)	(2)	(3)	(4)	(5)
Platform age	0.543***				0.515***
	(0.115)				(0.103)
Outstanding loan		0.289**			0.234*
		(0.118)			(0.120)
Shariah compliant platform			2.750**		2.578**
			(1.252)		(0.995)
Platform scope				-1.682	-1.751
				(1.900)	(1.648)
Controls					
Asset	0.063	0.126	0.284	0.203	0.107
	(0.153)	(0.184)	(0.173)	(0.183)	(0.134)
ROA	-0.244	-0.663	-0.384	-0.349	-0.391
	(0.447)	(0.460)	(0.366)	(0.370)	(0.477)
ROE	0.040**	0.040**	0.025	0.031*	0.026
	(0.017)	(0.018)	(0.017)	(0.017)	(0.018)
Default risk	-0.703	-3.039*	-3.982***	-2.657	-0.116
	(2.216)	(1.735)	(1.375)	(1.780)	(1.855)
Constant	-0.384	-2.630	1.729	4.148	-6.092
	(3.744)	(4.527)	(3.396)	(3.668)	(4.246)
Observations	85	85	85	85	85
adj. R-sq	0.170	0.063	0.040	0.050	0.259

Standard errors in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% levels

The dummy variable for shariah-compliant platforms is positive, indicating that Islamic fintech platforms attract significantly higher investor participation than conventional counterparts. This may reflect the growing demand for ethical and faith-based investment instruments, particularly in markets with large Muslim populations. This result is in line with studies such as Tawfik et al. (2025) and Ahmed & Sharif (2023), which find that shariah compliance enhances investor trust and broadens market appeal.

In contrast, platform scope does not exhibit a statistically significant effect in the full model, indicating that whether a platform operates nationally or internationally does not significantly influence investor participation. This indicates that investors may prioritize platform fundamentals – such as performance and credibility – over geographic scope.

Overall, the results highlight that platform maturity, scale of lending activity, and shariah compliance are key drivers of investor participation, while platform scope appears less relevant. The findings reinforce the importance of credibility, scale, and ethical positioning in shaping investor behavior within the fintech lending ecosystem.

CONCLUSION

This study provides novel empirical evidence on the determinants of investor participation in fintech lending platforms by utilizing firm-level data, offering a perspective that remains largely underexplored in the existing literature. Unlike prior studies that predominantly rely on campaign-level or aggregated national data, this study captures heterogeneity across individual platforms. The findings demonstrate that platform age, outstanding loan volume, and shariah compliance significantly influence investor participation, whereas platform scope has no meaningful effect. In particular, more mature, larger-scale platforms tend to attract substantially greater investor engagement, underscoring the importance of credibility, operational experience, and scale in reducing information asymmetry and building investor trust.

The implications of this study are both theoretical and practical. From a theoretical perspective, it extends signaling theory by demonstrating how firm-level attributes of fintech lending platforms serve as credible signals in markets characterized by high uncertainty, while also enriching the financial intermediation literature by positioning platforms as hybrid intermediaries that combine technological infrastructure with reputational capital. In addition, the inclusion of shariah compliance integrates insights from Islamic finance into mainstream fintech research, offering a more inclusive perspective on value-based investment behavior. In practice, the findings suggest that platform operators should strengthen their credibility, scale up lending activities, and leverage shariah positioning to attract investors. At the same time, regulators such as OJK should continue to promote transparency and stability to sustain investor confidence. Overall, this study provides a pioneering firm-level perspective that offers a more granular foundation for future research and policy development.

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The Innovation–Sustainability Paradox: Nonlinear Evidence from a Global Panel

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ABSTRACT

Research Originality: Departing from studies that assume a linear or monotonic innovation–sustainability link, this study is among the first to provide global panel evidence of a nonlinear, income-differentiated innovation–sustainability paradox, using an SDG index adjusted to avoid conceptual overlap with human development measures, and finds robust results from lagged identification.

Research Objectives: This study examines whether innovation consistently promotes sustainable development across 88 countries from 2018 to 2023, testing for nonlinearity and income-group heterogeneity.

Research Methods: A balanced panel fixed-effects framework estimates three specifications using an adjusted SDG index, namely linear, quadratic, and interaction models. Robustness is assessed via lagged GII, with structural heterogeneity examined through income-group subgroup analysis.

Empirical Results: GDP per capita positively predicts SDG performance with diminishing returns. GII follows an inverted U-shaped pattern (GII* ≈ 21.25), confirming the innovation–sustainability paradox. Most countries already operate past the turning point. Among Middle- and Low-Income economies, the threshold is higher (GII* ≈ 40.50), whereas High-Income economies exhibit a structural plateau.

Implications: Innovation policy must be calibrated to the stage of development. Advanced economies should redirect mature innovation systems toward sustainability objectives, while developing economies should expand capacity with directionality embedded from the outset.

Keywords: Global Innovation Index; sustainable development goals; nonlinear panel; inverted U-shaped; income heterogeneity

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INTRODUCTION

Sustainable development remains the benchmark for modern development policy, yet the progress towards the SDGs has become increasingly fragile. The 2025 global SDG review indicates that only around 18% of the targets are on track, with large proportions stagnating or regressing below the 2015 baseline. Several fundamental objectives, including hunger reduction, health, education, and climate action, continue to fall behind schedule (United Nations, 2025). The central analytical challenge is therefore not whether sustainable development is desirable, but which structural factors most reliably accelerate SDG achievement across diverse national settings (Malekpour et al., 2023).

Among the structural factors most frequently invoked in this debate is innovation. Innovation can improve productivity, enable technological upgrading, support cleaner production, and expand renewable-energy solutions, which makes it widely regarded as a strategic lever for sustainable development. Recent literature increasingly frames innovation policy not merely as a competitiveness tool, but as an instrument for transformative change capable of addressing societal grand challenges (Schot & Steinmueller, 2018; Geels et al., 2023; Mariani et al., 2022). However, the innovation-sustainability relationship is far from automatic. Innovation does not inherently guarantee ecological balance or social inclusion because its developmental contribution depends on how it is framed, governed, and directed. Recent SDG-oriented research confirms that high innovation performance does not necessarily translate into balanced progress across the full social, environmental, and institutional architecture of the SDGs (Pansera & Owen, 2018; Dzhunushalieva & Teuber, 2024; Suchitwarasan et al., 2024).

Two additional sources of complexity further challenge the assumption of a straightforward innovation-sustainability link. First, economy-wide rebound effects suggest that efficiency improvements from innovation often do not translate proportionally into lower energy use or reduced environmental pressure, because increases in production and consumption partially offset these gains (Brockway et al., 2021; Andrew & Pigosso, 2024). Second, recent studies report inverted-U and other nonlinear patterns in the innovation-sustainability relationship, indicating that innovation generates positive returns up to a threshold beyond which complexity, cost, and system-level trade-offs begin to weaken its net contribution (Leyva-de la Hiz & Bolívar-Ramos, 2022; H. Li et al., 2024). Alongside innovation, economic capacity constitutes a foundational determinant of SDG achievement, as higher-income countries typically possess greater fiscal space, stronger infrastructure, and broader access to social investment that enables sustainability-oriented spending (Sachs et al., 2020; Naqvi et al., 2025; Guillamón et al., 2025). However, even economic capacity exhibits diminishing returns at higher development levels, which raises parallel questions about the sustainability dividend of growth itself (Hickel, 2019).

Despite growing scholarly interest in the innovation-sustainability nexus, three important gaps persist in the literature. First, most empirical studies rely on narrow outcome measures such as carbon emissions or ecological footprints rather than comprehensive SDG performance metrics, which limits the generalisability of findings

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to the broader sustainability agenda. Second, the dominant empirical approach assumes a linear relationship between innovation and sustainability, and implicitly assumes that innovation is uniformly good, regardless of intensity. This assumption may hide threshold effects and diminishing returns that are theoretically plausible and policy relevant. Third, while Omri (2020) first raised the possibility that the sustainability effect of innovation varies systematically across income groups, this income-differentiated dimension remains underexplored in globally representative panel settings. Together, these gaps leave the central policy question unresolved. Does innovation reliably promote sustainable development as its intensity increases, or does its contribution weaken beyond a certain threshold?

This study addresses these gaps by examining the innovation-sustainability relationship across 88 countries over 2018-2023 using a panel fixed-effects framework that explicitly tests for nonlinear and income-differentiated effects. This study estimates three sequential specifications, namely a baseline linear model, a quadratic model that tests for diminishing returns in GII and GDP per capita, and an interaction model that assesses whether human development moderates the innovation effect. Lagged GII specifications serve as robustness checks. This study contributes empirical support for an innovation-sustainability paradox by demonstrating that the GII-SDG relationship follows an inverted-U pattern, with most countries already operating in the diminishing-returns region, and by showing that this paradox manifests with income-differentiated structural features that carry distinct policy implications for advanced and developing economies in the final years of the 2030 Agenda. Unlike Omri (2020), who documents income-differentiated effects of technological innovation on sustainability without explicitly modeling the underlying nonlinear turning point, or Le et al. (2025), who examine a linear innovation-led development pathway, this study provides a systematic estimate of the innovation–sustainability threshold and its income-conditioned variation within a globally representative fixed-effects framework.

METHODS

This study uses a balanced panel dataset of 88 countries observed annually from 2018 to 2023, yielding 528 observations. The sample period is bounded by the joint availability of all four data sources. The lower bound of 2018 corresponds to the earliest year for which consistent and complete observations across the SDG index, World Bank GDP estimates, WIPO's Global Innovation Index, and UNDP's Human Development Index were simultaneously available for the full country set. The upper bound of 2023 reflects a binding data constraint: the HDI series had not been updated beyond 2023 by UNDP at the time of data collection. Extending the panel to 2024 or 2025 would introduce systematic missingness in HDI that risks selection bias and would undermine the within-country fixed-effects identification strategy. The resulting six-year window (T = 6; N = 88; 528 observations) provides sufficient temporal variation for the nonlinear fixed-effects specifications estimated in this study. The dependent variable is an adjusted SDG index that excludes Goals 3 (Health) and 4 (Education) to reduce conceptual overlap with the Human Development Index, which is included as an

explanatory variable. The primary independent variables are the natural logarithm of GDP per capita in purchasing power parity terms (LNGDPPC), the Global Innovation Index (GII), and the Human Development Index (HDI). Data come from four sources: the Sustainable Development Reports, the World Bank database, the World Intellectual Property Organization (WIPO), and the United Nations Development Program (UNDP). Table 1 presents complete variable definitions and measurements.

Table 1. Definitions and Measurements of The Variables

Variables	Definition	Measurement
SDG Adj	Annual Sustainable Development Goals Index, excluding Goal 3 (Health) & 4 (Education) to reduce potential overlap with explanatory variables	Score (0-100)
LNGDPPC	Gross Domestic Product per capita in Purchasing Power Parity terms, capturing economic capacity across countries (log-transformed in estimation)	Constant international USD (log)
$LNGDPPC^2$	Squared term of the natural logarithm of GDP PPP/ Capita, included to capture potential nonlinear effects of economic development on sustainable development	$(\text{log GDP PPP/ Capita})^2$
GII	Annual Global Innovation Index of 88 countries, reflecting national innovation capacity and performance across multiple dimensions	Score (0-100)
GII^2	Squared term of the Global Innovation Index, used to test for diminishing returns and nonlinear relationships between innovation and sustainable development	Index squared
HDI	Annual Human Development Index of 88 countries, representing composite achievements in income, education, and life expectancy	Score (0-1)
GII_HDI	Interaction term between the Global Innovation Index and the Human Development Index, capturing the conditional effect of innovation depending on the level of human development	GII × HDI

This study estimates three sequential specifications to capture linear, nonlinear, and conditional relationships within a unified analytical framework:

$$SDG\ Adj_{it} = \beta_0 + \beta_1 LNGDPPC_{it} + \beta_2 GII_{it} + \beta_3 HDI_{it} + \epsilon_{it} \quad (1)$$

$$SDG\ Adj_{it} = \beta_0 + \beta_1 LNGDPPC_{it} + \beta_2 LNGDPPC^2_{it} + \beta_3 GII_{it} + \beta_4 GII^2_{it} + \beta_5 HDI_{it} + \epsilon_{it} \quad (2)$$

$$SDG\ Adj_{it} = \beta_0 + \beta_1 LNGDPPC_{it} + \beta_2 GII_{it} + \beta_3 HDI_{it} + \beta_4 GII_HDI_{it} + \in_{it} \quad (3)$$

The baseline model (1) estimates the average linear association between structural development factors and adjusted SDG performance. The nonlinear model (2) introduces quadratic terms for LNGDPPC and GII to test for diminishing returns, consistent with the innovation-sustainability paradox hypothesis. The interaction model (3) assesses whether the sustainability effect of innovation depends on the level of human development.

Panel fixed effects specification is selected following Chow and Hausman tests. The results show that the Chow test rejects pooled OLS, and the Hausman test indicates that fixed effects is preferred over random effects. Fixed effects estimation controls for time-invariant country-specific heterogeneity that may correlate with the explanatory variables, thereby reducing omitted variable bias (Baloch et al., 2019). To assess whether the main findings are sensitive to potential simultaneity bias, additional specifications

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replace contemporaneous GII with one-period lagged values. White cross-section robust standard errors address heteroskedasticity and contemporaneous cross-sectional dependence across the heterogeneous country sample (Jiakui et al., 2023).

RESULTS AND DISCUSSION

This study finds that the innovation–sustainability relationship is nonlinear and income-differentiated rather than uniformly positive, providing cross-country panel evidence for an innovation–sustainability paradox. GDP per capita exerts a robust positive effect on adjusted SDG performance across all specifications, yet this contribution diminishes at higher income levels. The Global Innovation Index follows an inverted-U relationship with sustainable development, with a turning point near the lower bound of the sample distribution, indicating that most countries already operate in the diminishing-returns region where further innovation intensity generates progressively smaller sustainability gains. Robustness checks using lagged GII specifications confirm that reverse causality does not drive this pattern. Subgroup analysis further reveals that the paradox is income-differentiated, with developing economies retaining positive innovation-sustainability returns up to a substantially higher threshold. In contrast, advanced economies exhibit a structural plateau where aggregate innovation volume no longer drives SDG performance in a statistically detectable way.

Table 2. Descriptive Statistics of The Variables 2018-2023

Variable	Mean	Std. Dev.	Min.	Max.
SDGs Adj.	68.88	8.34	50.04	84.52
LNGDPPC	9.81	1.11	7.15	11.88
GII	33.82	11.98	11.6	64.2
HDI	0.77	0.15	0.39	0.97

Table 2 shows substantial cross-country variation in all variables. The adjusted SDG score ranges confirm sufficient outcome variation to support cross-country estimation, while GII ranges and mean indicate that the sample spans countries at very different stages of innovation-system maturity. Importantly, the strong pairwise correlations among LNGDPPC, GII, and HDI reported in Table 3, particularly the near-perfect positive correlation between income and human development, anticipate multicollinearity challenges in the full-sample estimation that are addressed through sequential specification and subgroup analysis.

Moving beyond the descriptive profile, Table 4 reports the baseline fixed-effects estimates. This model uses adjusted SDG scores as the dependent variable, with GDP per capita, innovation capacity, and human development as the primary independent variables to determine the average linear association between these structural factors and SDG performance, prior to incorporating nonlinear terms and interaction effects.

Table 4 reports the baseline fixed-effects estimates. The model is jointly significant and yields a high adjusted R^2, reflecting the combined explanatory power of the structural variables alongside cross-country fixed effects. Economic capacity exerts a strong positive

effect on adjusted SDG performance, confirming that higher-income countries possess greater fiscal space and institutional capacity to finance sustainability-oriented investment, consistent with recent cross-country evidence (Guillamón et al., 2025; Naqvi et al., 2025). By contrast, GII enters with a negative and statistically significant coefficient, indicating that in a linear specification, higher innovation intensity associates with lower SDG performance (Le et al., 2025).

Table 3. Correlation Matrix of the Variables

Variable	SDGs Adj	LNGDPPC	GII	HDI
SDGs Adj.	1.000			
LNGDPPC	0.676	1.000		
GII	0.766	0.764	1.000	
HDI	0.770	0.955	0.814	1.000

Table 4. Estimated Results of the Baseline Model

Variable	Coefficient	t-Statistic	Prob.
Constant	45.647	14.943	0.000
LNGDPPC	2.553	9.169	0.000
GII	-0.070	-5.083	0.000
HDI	0.737	0.219	0.826
Adjusted R-Square	0.995		
F-Statistic	1305.819		
Prob. (F-Statistic)	0.000		

Rather than suggesting that innovation harms sustainability, this result signals that a linear framework is insufficient to capture the full structure of the relationship, which directly motivates the nonlinear specification estimated in Table 5. HDI does not emerge as a statistically significant predictor once income and innovation are jointly controlled for, an expected result given the near-perfect correlation between HDI and LNGDPPC ($r = 0.955$) documented in Table 3, which prevents the fixed-effects estimator from precisely separating their independent contributions. All subsequent HDI results should be interpreted in light of this structural overlap.

Following the preliminary regression analysis, Table 5 displays the outcomes of a nonlinear model, incorporating squared terms for LNGDPPC and GII. Consequently, the nonlinear model offers a more refined understanding of the innovation–sustainability relationship than the initial linear framework. Table 5 reveals that the innovation-sustainability relationship follows an inverted-U pattern rather than a monotonic one. GDP per capita retains a strong positive effect on adjusted SDG performance while its squared term enters negatively, confirming that economic capacity drives sustainability outcomes with diminishing returns at higher income levels, consistent with environmental

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Kuznets curve interpretations (Stern, 2017; Nathaniel, 2021). More substantively, GII enters positively while its squared term is negative and statistically significant, indicating that innovation contributes to sustainable development up to a threshold beyond which its marginal effect weakens.

Table 5. Estimated Results of the Nonlinear Model

Variable	Coefficient	t-Statistic	Prob.
Constant	-26.529	-2.199	0.028
LNGDPPC	16.925	7.214	0.000
$LNGDPPC^2$	-0.705	-6.167	0.000
GII	0.085	2.082	0.037
GII^2	-0.002	-3.406	0.001
HDI	-2.582	-0.777	0.437
Adjusted R-Square	0.995		
F-Statistic	1383.352		
Prob. (F-Statistic)	0.000		

The turning point is estimated as follows:

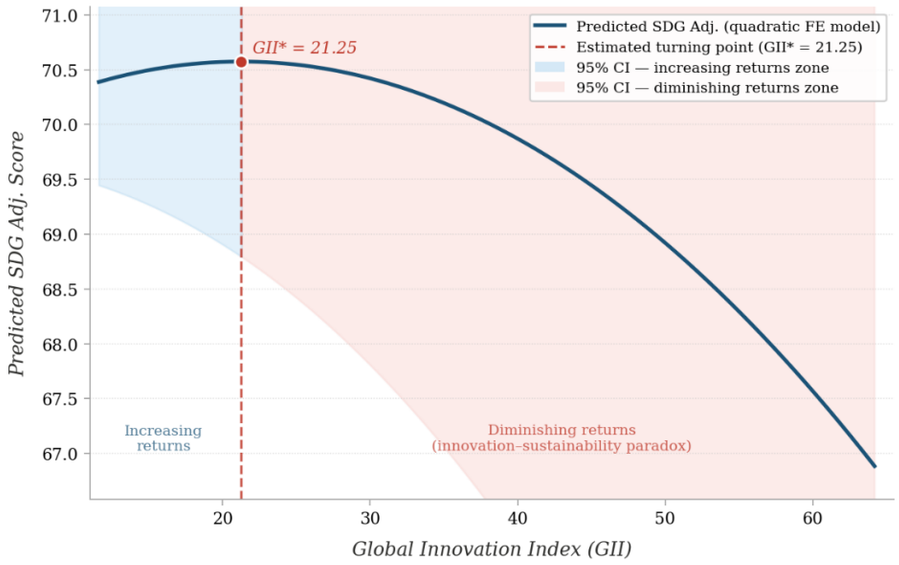
$$GII^* = -\frac{\beta(GII)}{2\beta(GII^2)} = -\frac{0.085}{2(-0.002)} = -\frac{0.085}{-0.004} \approx 21.25 \quad (4)$$

Because this value falls near the lower bound of the observed GII range (11.6-64.2), most countries in the sample already operate in the diminishing-returns region where further innovation intensity generates progressively smaller sustainability gains. Figure 1 plots the predicted nonlinear contribution of GII to adjusted SDG performance across the observed range, confirming that the inverted-U pattern is economically meaningful rather than a statistical artifact.

This finding extends and nuances prior evidence on the innovation-sustainability nexus. Omri (2020) shows that the sustainability effect of technological innovation varies systematically by income group, while Chaparro-Banegas et al. (2023) demonstrate that innovation facilitators promote SDG achievement. However, growth limits and ecosystem boundaries constrain their effects. The present study adds that this variation operates within a nonlinear structure where innovation remains beneficial, but its sustainability payoff diminishes as intensity rises. At a more granular level, Leyva-de la Hiz & Bolívar-Ramos (2022) document a similar inverted-U relationship between green innovative activities and firm performance, and Li et al. (2024) describe a green innovation paradox in which carbon-emission reduction efforts generate diminishing technological returns beyond a threshold. A plausible mechanism connecting these patterns is the rebound effect. Efficiency gains from innovation often trigger additional production and consumption that partially offset environmental benefits (Andrew & Pigosso, 2024; Mallari et al., 2025). This evidence supports the interpretation that sustainable development outcomes depend not on how much innovation a country

produces, but on whether that innovation is directed toward social and ecological objectives rather than productivity and scale expansion alone (Dzhunushalieva & Teuber, 2024; Suchitwarasan et al., 2024).

Figure 1. Innovation-Sustainability Paradox: Evidence of Diminishing Returns



Source: author's calculation

Table 6 presents the interaction model estimates. GII retains a negative and statistically significant direct effect, consistent with the baseline results. This suggests that innovation does not automatically promote sustainable development in the absence of directional governance (Zadegan & Ghazinoory, 2026). This finding is further supported by Cetinguc et al. (2023), who demonstrate, using GII and HDI jointly across income groups, that income level itself absorbs the moderating role of human development in innovation-outcome relationships. Agarwalla & Sahu (2024) also point out that innovation and human capital each make a non-synergistic contribution to sustainable development. This explains why the GII and HDI interaction term is not significant. The two variables operate independently, rather than moderating one another.

Table 6. Estimated Results of the Interaction Model

Variable	Coefficient	t-Statistic	Prob.
Constant	48.325	13.563	0.000
LNGDPPC	2.570	9.233	0.000
GII	-0.148	-2.677	0.001
HDI	-3.386	-0.771	0.441
GII_HDI	0.108	1.455	0.146
Adjusted R-Square	0.995		
F-Statistic	1294.797		
Prob. (F-Statistic)	0.000		

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Furthermore, published official data sources do not provide sufficient evidence of a systematic moderating role for human development in the full sample (Del-Aguila-Arcentales et al., 2023). The most plausible explanation for the null GII_HDI result is the consistency with the structural overlap documented in Table 4. When LNGDPPC already absorbs most of the developmental information contained in HDI, compounding multicollinearity further suppresses any detectable conditional moderation through the interaction term.

Table 7. Robustness Check Results: Lagged GII Specifications (RC1 and RC2)

Variable	RC1 Lag-Linear	RC2 Lag-Nonlinear
Constant	53.216***	-31.634**
LNGDPPC	2.062*	19.078***
$LNGDPPC^2$	–	-0.837***
GII t-1	-0.058**	0.073*
GII^2 t-1	–	-0.002***
HDI	-3.199	-6.620*
Turning point GII* t-1	≈ 20.24	
Adj. R-Square	0.997	
Observations	440	
SE Method	White diagonal	

Note(s): ***, **, and * indicate significance at 1%, 5% and 10% levels respectively
Both specifications are estimated using cross-section fixed effects over the reduced sample 2019–2023 (T=5), following one-period lag transformation of GII. White diagonal standard errors are applied to address heteroskedasticity.

Table 7 reports the robustness check results using one-period lagged GII specifications. RC1 confirms that the negative linear association between innovation capacity and adjusted SDG performance persists when GII is lagged, ruling out contemporaneous simultaneity as a driver of the baseline result. RC2 confirms that the inverted-U relationship documented in the nonlinear model is likewise robust. The quadratic structure is preserved, and the estimated turning point at GII* ≈ 20.24 remains nearly identical to the contemporaneous estimate, confirming structural stability across specifications. The near-identical turning points across contemporaneous and lagged specifications indicate that the innovation-sustainability paradox reflects a genuine temporal mechanism rather than a statistical artifact of reverse causality (Brockway et al., 2021; Le et al., 2025).

Table 8 presents the subgroup estimates by World Bank income classification. For Middle- and Low-Income economies, the inverted-U relationship is statistically confirmed. GII enters positively while its squared term enters negatively, yielding an estimated turning point of GII* ≈ 40.50. Because most developing economies in the sample operate below this threshold, they remain in the ascending segment of the innovation-sustainability curve where incremental innovation capacity continues to generate positive sustainability returns. This result extends Omri (2020), who shows that the sustainability dividend of technological innovation is stronger and more direct in developing economies, by locating

this advantage within the specific nonlinear structure of the relationship. Economic capacity likewise retains its positive and diminishing-returns pattern in this subgroup, indicating that both income growth and innovation remain active structural drivers of SDG performance for developing economies. The negative marginal significance of HDI here reflects a collinearity-induced sign reversal in the presence of LNGDPPC, consistent with the structural overlap established in Table 4, rather than a genuine adverse human development effect (Soergel et al., 2021).

Table 8. Subgroup Analysis: Nonlinear Model by World Bank Income Group

Variable	Full Sample	High Income	Middle and Low Income
Constant	-26.529**	90.034***	-37.349*
LNGDPPC	16.925***	-2.625	20.176***
$LNGDPPC^2$	-0.705***	0.034	-0.941***
GII	0.085**	0.074	0.127**
GII^2	-0.002***	-0.001	-0.002*
HDI	-2.582	8.597	-6.411*
Turning point GII* t-1	≈ 20.24	≈ 29.88 (ns)	≈ 40.5
Adj. R-Square	0.995	0.998	0.995
Observations	528	210	318
Countries	88	35	53

Note(s): ***, **, and * indicate significance at 1%, 5% and 10% levels respectively
All specifications use cross-section and period fixed effects with White cross-section robust standard errors. Full sample results reproduced from Table 5. Income group classification follows World Bank FY2026 definitions. (ns) = turning point not statistically meaningful due to insignificant GII coefficients in the High-Income subgroup.

For High Income economies, the pattern diverges markedly. None of the structural regressors reach conventional significance thresholds in the within-country estimation. The variation in SDG scores within developed countries is very small, making it difficult for fixed effects to detect any marginal effects. This result is consistent with Masali et al. (2026), who demonstrate that high-income countries are approaching SDG saturation ceilings, leaving little marginal room for innovation intensity alone to drive further improvement within the observed period. Manzoor et al. (2023) use a fixed-effects panel dataset across income groups for innovation and outcomes in innovative countries, and support the argument that the effects of innovation differ structurally across income groups. Chaparro-Banegas et al. (2023) and Kroll et al. (2019) also observe that even for innovation-intensive countries, ecological limits and structural growth conditions constrain the sustainability dividend of further innovation, while Dzhunushalieva & Teuber (2024) show that high innovation performance does not automatically translate into balanced progress across the full SDG architecture. Collectively, these studies suggest that short-run variation in aggregate innovation volume no longer drives SDG performance in a statistically detectable manner. Although a turning point of GII* ≈ 29.88 can be arithmetically derived from the High-Income coefficients, it carries no substantive interpretation given the statistical insignificance of the underlying estimates.

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Taken together, the four estimation stages challenge the conventional assumption that more innovation, more income, and more human development will automatically and indefinitely improve sustainable development performance. The evidence supports a structural-development perspective in which SDG achievement depends on how economic capacity, innovation systems, and human capabilities are configured relative to sustainability objectives, rather than on their accumulation alone. Economic growth remains necessary but subject to diminishing sustainability returns. Innovation is productive but not inherently sustainability-enhancing. Human development is foundational but largely indirect in its observable statistical contribution once other structural conditions are controlled for. The pathway to SDG progress is therefore not a linear sequence from income accumulation to innovation intensity to sustainability outcomes, but a contingent and income-differentiated process in which the developmental value of innovation depends critically on its direction, governance, and alignment with the full social and ecological architecture of the 2030 Agenda (Schot & Steinmueller, 2018; Geels et al., 2023). The capability-building strategies must embed sustainability directionality from the outset and integrate with investments in human capital and institutional effectiveness (Kirchherr et al., 2023; OECD, 2024; World Bank, 2024). Across both contexts, human development should be positioned as foundational structural infrastructure for sustainability-oriented transformation rather than as a residual policy objective (UNDP, 2024).

CONCLUSION

This study examined whether innovation consistently promotes sustainable development across 88 countries from 2018 to 2023 using a panel fixed-effects framework. Four findings emerge. First, GDP per capita exerts a robust positive effect on adjusted SDG performance, subject to diminishing returns at higher income levels. Second, the Global Innovation Index follows an inverted-U pattern with a turning point at GII* ≈ 21.25, confirmed by lagged specifications at GII* ≈ 20.24, providing empirical support for an innovation-sustainability paradox in which most countries already operate in the diminishing-returns region. Third, HDI does not emerge as a statistically significant independent predictor in the full sample, most plausibly owing to its strong structural overlap with income. Fourth, the paradox is income-differentiated. Middle- and Low-income economies retain a higher turning point at GII* ≈ 40.50 and continue to benefit from innovation capacity expansion. In contrast, High-income economies exhibit a structural plateau where aggregate innovation volume no longer drives SDG performance in a statistically detectable way. Together, these findings reframe SDG achievement as contingent on how development capacities are configured and directed toward sustainability objectives, rather than merely accumulated.

The central policy imperative is not to maximize innovation volume but to govern its direction. Advanced economies should prioritize redirecting mature innovation systems toward decarbonization, circular production, and socially inclusive technological change, given that aggregate innovation intensity no longer drives SDG performance. For developing economies, the window of opportunity to expand innovation capacity while sustainability returns remain positive is real but conditional. Several limitations point toward productive directions for

future research. The high inter-correlations among structural regressors constrain the precision of HDI estimates and the interaction term. Future studies employing disaggregated human development indicators, sector-specific innovation measures, and dynamic panel or threshold regression techniques would help clarify the mechanisms and conditions under which the innovation-sustainability paradox materializes across diverse development contexts.

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Do Village Funds and Tobacco Excise Revenue Sharing Improve Human Development?

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ABSTRACT

Research Originality: This study contributes to the literature by examining the effects of Village Funds and Tobacco Excise Revenue Sharing Funds on human development in Central Java and underscores the lack of studies that assess these effects using individual HDI indicators as robustness measures.

Research Objectives: This study aims to analyze whether fiscal transfers significantly improve HDI in Central Java.

Research Methods: This study uses panel data from 35 districts/cities in Central Java during 2016-2023 and employs a Fixed Effects Model. Robustness tests use life expectancy, mean years of schooling, and per capita income.

Empirical Results: Village Funds and Tobacco Excise Revenue Sharing improve human development in Central Java. However, impacts vary by HDI dimension. These fiscal transfer instruments mainly improve life expectancy and income, whereas mean years of schooling show no statistically significant results. This suggests stronger contributions for health and income than for education.

Implications: These findings suggest that fiscal transfer policies should improve targeting and effectiveness to support long-term human development and reduce regional disparities, especially in education outcomes.

Keywords:
village funds; tobacco excise revenue sharing; welfare outcomes; intergovernmental fiscal transfers; human development

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INTRODUCTION

Human development remains a key challenge in sustainable economic development, as it reflects the quality of human capital and individuals' ability to participate productively in economic activities (Jie & Lan, 2024). Although economic theory emphasizes that improvements in human resources, particularly higher labor quality and productivity, are essential drivers of long-term economic growth, disparities in human development persist across regions (Bekele et al., 2024). In development economics, investment in education and health is considered a fundamental mechanism for improving welfare, reducing poverty, and strengthening socioeconomic resilience, especially in developing countries (Sultana et al., 2022). These issues highlight that improvements in income alone are insufficient if human development outcomes remain uneven.

The importance of this issue is reflected in the Human Development Index (HDI), which is widely used as a multidimensional measure capturing achievements in health, education, and income, providing a broader alternative to GDP-based indicators (Zhang & Danish, 2019; Lescano et al., 2024; Susilo et al., 2026). HDI not only measures development outcomes but also reflects the effectiveness of public policy in improving living standards and access to basic services (Hilwa et al., 2026). Regions with higher HDI generally demonstrate stronger human capital formation and better economic opportunities, which contribute to higher productivity and lower vulnerability (Asadullah & Savoia, 2018). However, despite continuous economic progress in many developing countries, persistent regional disparities in human development indicate that development gains are not evenly distributed and require more inclusive policy interventions (Lian et al., 2023).

In Java, despite being the center of Indonesia's economy and government, disparities in economic welfare remain a major development challenge, underscoring the importance of regional-level analysis to better understand uneven development outcomes across districts and cities (Black et al., 2025). Regencies and municipalities in Central Java Province exhibit a diverse economic structure, combining agricultural, industrial, and service sectors, which contributes to differences in fiscal capacity and development outcomes across regions. Statistics Indonesia (BPS) reports that Central Java's Human Development Index (HDI) increased steadily from 69.98 in 2016 to 73.39 in 2023, indicating continuous improvement over time; however, it remains below the national average, suggesting structural constraints in improving welfare outcomes. This improvement is nevertheless accompanied by persistent disparities in HDI across districts and municipalities in the province, reflecting uneven human development performance due to differences in local governments' ability to translate fiscal resources into human development outcomes, making Central Java Province a relevant empirical case for examining human development performance under fiscal decentralization (Sjaf et al., 2025). However, empirical evidence on districts/cities in Central Java remains relatively limited.

Fiscal decentralization has been widely recognized as a policy instrument aimed at improving the efficiency of public service delivery and enhancing regional development performance by allocating resources to subnational governments, while also stimulating regional economic activity and strengthening human development outcomes (Bacarreza et

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al., 2020; Jin & Jakovljevic, 2023). In practice, however, regional fiscal disparities remain significant, as many districts and cities still face limited capacity to generate own-source revenue, making it difficult to finance development expenditures independently (Yimenu, 2023). This condition creates a dependency on intergovernmental fiscal transfers as a strategic mechanism to equalize fiscal capacity and reduce inequality in public service delivery. Several studies argue that fiscal transfers can improve welfare by encouraging local governments to expand spending on education and healthcare, particularly in less developed regions (Hung & Thanh, 2022). In Indonesia, fiscal transfers are essential components of decentralized governance that aim to reduce fiscal disparities and strengthen local government capacity across varying regional revenue conditions, as evidenced by the uneven spatial distribution of fiscal revenues and the need to modify transfer allocation formulas to improve equity (Akita et al., 2021).

Among Indonesia's fiscal transfer instruments, Village Funds are among the most important mechanisms for promoting inclusive development. Empirical evidence suggests that Village Funds can contribute to rural development, employment creation, and welfare improvement by expanding access to economic opportunities and public facilities (Arifin et al., 2020). As a result, Village Funds are expected to improve human development outcomes, particularly in regions where development challenges remain concentrated in rural areas. Another important fiscal instrument is the Tobacco Excise Revenue Sharing Fund (DBHCHT). This scheme allocates a portion of tobacco excise revenues to local governments to finance healthcare programs, law enforcement activities, social welfare initiatives, and other development-related expenditures (Yandri et al., 2020). The rationale underlying DBHCHT is that fiscal resources generated from tobacco consumption should help mitigate its social and health consequences while supporting broader welfare objectives. Therefore, DBHCHT is also expected to contribute positively to human development, particularly by improving health outcomes and public service provision.

Empirical research on Village Funds and human development has produced mixed findings. Some studies find a positive effect (Pandiangan et al., 2021); others find no effect (Hilmawan et al., 2023). The relationship between DBHCHT and human development is also debated: some studies find no effect, others report outcomes that reduce or enhance human development (Mgammal, 2024; Saputra & Doddy, 2026). These findings suggest that earlier studies have not fully considered the combined effects of Village Funds and DBHCHT, nor how these fiscal transfer instruments interact to influence human development outcomes.

Human development is influenced not only by fiscal transfers but also by regional economic and fiscal conditions, with stronger fiscal capacity and higher income improving performance, and higher unemployment reducing it. However, the evidence is inconclusive, and different studies report varying effects of HDI on regional conditions and structural characteristics (Hung & Thanh, 2022; Stijepic, 2021; Saputra & Doddy, 2026). Therefore, controlling for these factors is necessary to understand the fiscal determinants of HDI better, as earlier studies have not fully considered the effects of fiscal instruments and macroeconomic factors on disparities in human development across regions.

This study aims to address empirical gaps by examining the impact of fiscal transfer instruments on human development in Indonesia, focusing on Village Funds and DBHCHT across districts/cities in Central Java. Existing studies have analyzed fiscal transfers at the aggregate level or through a single transfer scheme, thereby limiting understanding of how different types of transfers influence human development outcomes at the subnational level. Most empirical evidence relies on national or cross-country analyses, while district-level heterogeneity within provinces remains underexplored.

The study's main novelty lies in three aspects. Firstly, it integrates Village Funds and DBHCHT within a unified analytical framework, enabling a more comprehensive assessment of their combined effects on human development. Secondly, it enhances empirical robustness by incorporating disaggregated HDI components to capture multidimensional effects of fiscal transfers. Thirdly, it provides a district-level empirical analysis of fiscal transfers and human development using panel data from 35 districts and municipalities in Central Java, allowing for a more detailed examination of regional variations in development outcomes. Based on these motivations, this study aims to analyze the effects of Village Funds and DBHCHT on human development across districts/cities in Central Java during the period 2016-2023. Using panel data analysis, this study seeks to provide new empirical evidence on how fiscal transfer instruments influence human development outcomes and to contribute to the ongoing debate on the effectiveness of fiscal transfers in reducing regional disparities in developing countries.

METHODS

This study uses panel data regression analysis with fixed- and random-effects models. The model is chosen using formal specification tests. The dataset covers the period 2016-2023 and comprises 280 observations from 35 districts in Central Java Province. The observation period was selected based on the availability and consistency of district-level data. Central Java was selected as the unit of analysis because it receives substantial allocations of both Village Funds and DBHCHT, and has several tobacco-producing regions and tobacco-related industries. Despite these significant fiscal transfers, disparities in HDI achievement across districts and municipalities remain, suggesting that improvements in human development outcomes are not evenly distributed. This raises questions about the effectiveness of fiscal transfers in enhancing human welfare. Furthermore, the availability of complete and consistent district-level panel data enables a robust empirical assessment of temporal and regional variations. These characteristics justify Central Java as a relevant unit of analysis.

This study uses five key variables. The dependent variable is the Human Development Index (HDI). For robustness analysis, the HDI is disaggregated into Life Expectancy (AHH), Mean Years of Schooling (RRLS), and Per Capita Income (PPP). The main independent variables are Village Funds and Tobacco Excise Revenue Sharing Funds (DBHCHT). Control variables include Regional Original Revenue (PAD), Gross Regional Domestic Product per capita (GRDP per capita), and the Open Unemployment Rate (TPT). All data are obtained from official sources, namely the Central Statistics Agency

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(BPS) and the Directorate General of Fiscal Balance (DJPK), ensuring reliability and consistency. The equation model in this study is as follows:

$$\text{IPM}_{it} = \beta_0 + \beta_1\text{LDD}_{it} + \beta_2\text{LDBHCHT}_{it} + \beta_3\text{LPAD}_{it} + \beta_4\ \text{LPDRB}_{it} - \beta_5\text{TPT}_{it} + \varepsilon_{it} \quad (1)$$

$$\text{AHH}_{it} = \beta_0 + \beta_1\text{LDD}_{it} + \beta_2\text{LDBHCHT}_{it} + \beta_3\text{LPAD}_{it} + \beta_4\ \text{LPDRB}_{it} - \beta_5\text{TPT}_{it} + \varepsilon_{it} \quad (2)$$

$$\text{RRLS}_{it} = \beta_0 + \beta_1\text{LDD}_{it} + \beta_2\text{LDBHCHT}_{it} + \beta_3\text{LPAD}_{it} + \beta_4\ \text{LPDRB}_{it} - \beta_5\text{TPT}_{i} + \varepsilon_{it} \quad (3)$$

$$\text{LPPP}_{it} = \beta_0 + \beta_1\text{LDD}_{it} + \beta_2\text{LDBHCHT}_{it} + \beta_3\text{LPAD}_{it} + \beta_4\ \text{LPDRB}_{it} - \beta_5\text{TPT}_{it} + \varepsilon_{\text{it}} \quad (4)$$

Where IPM$_{it}$ is the Human Development Index in districts/cities I in period t. AHH$_{it}$ is the Life Expectancy Rate, RRLS$_{it}$ is the Mean Years of Schooling, LPPP$_{it}$ is the logarithm of Per Capita Income, LDD$_{it}$ is the logarithm of the Village Fund, LDBHCHT$_{it}$ is the logarithm of the Tobacco Excise Revenue Sharing Fund, LPAD$_{it}$ is the logarithm of Regional Original Revenue, LPDRB$_{it}$ is the logarithm of Gross Regional Domestic Product per Capita, and TPT$_{it}$ is the Open Unemployment Rate. β0 is a constant, whereas β1- β5 are coefficients; Index I shows district/city (1,2, …, 35) and t indicates a time period (2016-2023). ε_{it} is an error term.

This study uses a fixed-effects model to control for time-invariant characteristics across districts/cities, reducing potential endogeneity arising from omitted-variable bias and unobserved regional heterogeneity. Data were cleaned, missing-value checks were conducted, outliers were treated, and logarithmic transformation was applied. Descriptive statistics were used to summarise the data. A panel data estimation model was employed with fixed- and random-effects; selection was based on Chow and Hausman tests. Robust standard errors clustered at the district/city level were applied to ensure reliable inference, and multicollinearity was assessed using a correlation matrix, with coefficients below 0.80 indicating no serious multicollinearity. Statistical significance was evaluated at the 5% level.

RESULTS AND DISCUSSION

The study's findings show that Village Funds and DBHCHT improve human development in Central Java. Panel data estimation shows that both instruments have a positive effect on the HDI, suggesting that higher transfers lead to better development outcomes. The results also reveal that the control variables, namely regional original revenue, gross regional domestic product per capita, and open unemployment rate, are significantly associated with HDI. Robustness tests using life expectancy, mean years of schooling, and per capita expenditure provide further evidence that the effects of fiscal transfers extend across multiple dimensions of human development. The detailed results are presented below.

Table 1 presents the descriptive statistics. The dataset consists of 35 districts/cities over the 2016-2023 period. HDI is an index, while the rest are measured in their units. There are disparities in the values of several variables across districts/cities. These variations suggest differences in human development, fiscal conditions, economic performance, and labor market characteristics across the regions (see Table 1).

Table 1. Descriptive Statistics

Variables	Obs	Mean	Std. Dev	Min	Max
IPM	280	72.467	4.478	63.980	84.990
AHH	280	74.872	1.870	68.410	77.930
RRLS	280	7.815	1.296	2.080	11.240
LPPP	280	13.797	0.252	13.327	14.688
LDD	280	15.979	7.288	0.000	20.021
LDBHCHT	280	16.199	0.665	15.548	19.289
LPAD	280	19.687	0.441	18.726	21.765
LPDRB	280	3.207	0.503	2.482	4.558
TPT	280	5.077	1.852	1.76	9.97

Source: The author's calculations (2026)

Table 2 presents the results of the model selection process. A series of specification tests was conducted to determine the most suitable model among the Common Effects Model, the Fixed Effects Model, and the Random Effects Model. The results suggest that the Fixed Effects Model is the most appropriate. Accordingly, it has been adopted in this study.

Table 2. Chow and Hausman Test Results

	Probability			
Effect Test	**Model I (IPM)**	**Model II (AHH)**	**Model III (RRLS)**	**Model IV (LPPP)**
Chow	0.0000	0.0000	0.0000	0.0000
Hausman	0.0000	0.0000	0.0005	0.0000
Conclusion	FEM	FEM	FEM	FEM

Source: The author's calculations (2026)

Table 3. Multicollinearity Test Results: Pairwise Correlations

Variables	LDD	LDBHCHT	LPAD	LPDRB	TPT
LDD	1	0.23	-0.10	-0.63	-0.27
LDBHCHT	0.23	1	0.05	0.19	-0.29
LPAD	-0.10	0.05	1	0.41	0.24
LPDRB	-0.63	0.19	0.41	1	0.14
TPT	-0.27	-0.29	0.24	0.14	1

Source: The author's calculations (2026)

The results in Table 3 show that the independent variables are not highly correlated. This means the panel data regression model is not affected by multicollinearity. All

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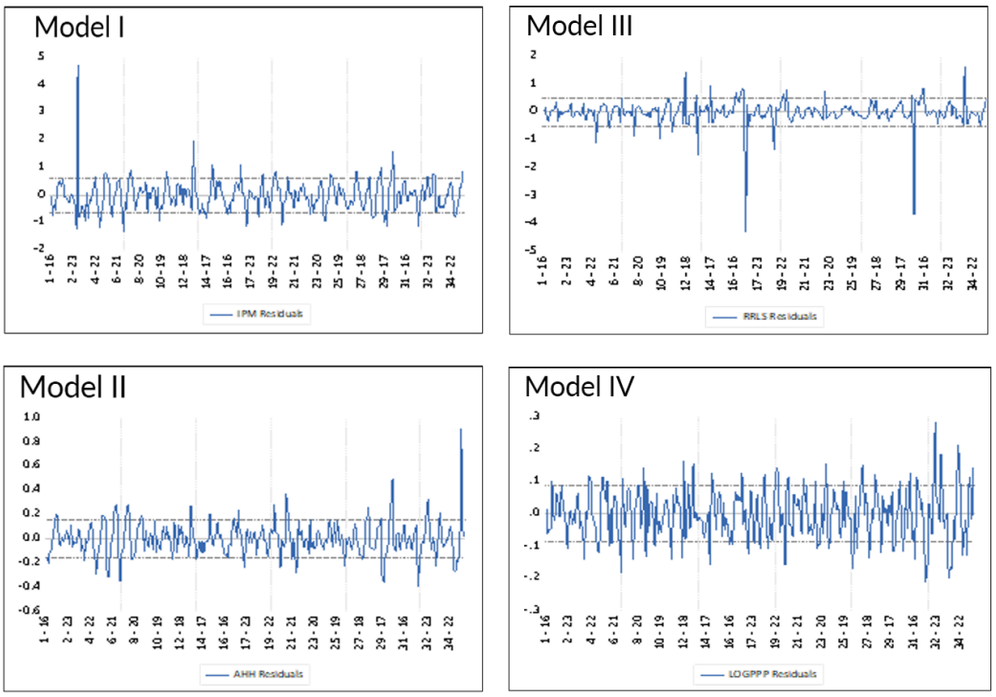
estimation models use the same independent variables, so the correlation structure and test results are the same for all model specifications.

As shown in Figure 1, the residual plots for Models I, II, III, and IV show that the errors are randomly scattered around zero. This means the variance of the errors does not change across observations. This indicates that the homoscedasticity assumption is satisfied, meaning the models are reliable for further analysis.

Figure 1. Residual Graph Heteroscedasticity Test



Source: The author's calculations (2026)

Based on Table 4, the F-test results suggest that all estimated models are jointly significant. This implies that the independent variables collectively influence the dependent variables. The t-test results further show that all explanatory variables significantly affect HDI. Furthermore, robustness analysis using life expectancy, mean years of schooling, and per capita income confirms the consistency of the main findings. Therefore, fiscal transfers constitute an important instrument for improving human development outcomes, particularly in the health and income dimensions.

The results reveal a positive association between Village Funds and human development. This occurs because Village Funds allow villages to improve infrastructure, healthcare services, and community empowerment programs, directly improving welfare. Improved access to economic opportunities and basic services is achieved through better village roads, sanitation facilities, and public services, contributing to higher human development outcomes. This is consistent with the findings of Sijabat (2024) and Permatasari et al. (2021) in Indonesia, and with those of Akita et al. (2021), who found

that Village Funds improve welfare through infrastructure expansion, poverty reduction, and sustainable rural development. Akita et al. (2021) also highlight the importance of intergovernmental fiscal transfers in reducing regional disparities and supporting local development outcomes. Collectively, these studies suggest that fiscal transfers play an important role in expanding access to public services and improving community welfare. The present study shows that Village Funds' contributions are more apparent in the health and income dimensions than in educational attainment, indicating that the benefits of Village Funds are not distributed evenly across all aspects of human development.

Table 4. Panel Regression Estimation Results

Variables	Model I (IPM)	Model II (AHH)	Model III (RRLS)	Model IV (LPPP)
C	-21.35***	56.58***	-9.53***	1.71***
	(4.488)	(1.105)	(3.657)	(0.625)
LDD	2.17***	0.43***	0.28	0.27***
	(0.323)	(0.079)	(0.263)	(0.045)
LDBHCHT	1.93***	0.50***	0.14	0.21***
	(0.195)	(0.048)	(0.159)	(0.027)
LPAD	0.57**	0.11*	0.20	0.08***
	(0.271)	(0.066)	(0.221)	(0.037)
LPDRB	4.87***	0.17	1.89***	0.75***
	(0.865)	(0.213)	(0.705)	(0.120)
TPT	0.16***	0.05***	0.04	0.02***
	(0.040)	(0.010)	(0.033)	(0.005)
Adj R-squared	0.980489	0.993218	0.845324	0.845324
Prob F-Stat	0.000000	0.000000	0.000000	0.000000

Note: *** significant at 1%, ** significant at 5%, * significant at 10%
Source: The author's calculations (2026)

Meanwhile, the results reveal that DBHCHT also has a positive effect on human development. This condition may occur because DBHCHT is designed to support health services, labor welfare programs, social protection initiatives, and other public service activities. Through these programs, local governments can improve healthcare access, strengthen social assistance mechanisms, and enhance community welfare. This is consistent with Mgammal (2024), who showed that tobacco-related tax revenues can support human development by improving public health and providing public resources for social and economic development. Similar conclusions were reported by Ahsan et al. (2024), who highlighted the importance of DBHCHT as a fiscal instrument for financing development programs that improve community welfare and support socio-economic development in local regions.

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These findings suggest that tobacco excise revenue-sharing funds strengthen local government capacity in providing welfare-oriented programs. Nevertheless, previous studies generally focus on the overall welfare effects of DBHCHT and provide limited evidence of its contribution to specific dimensions of human development. This study shows that DBHCHT's primary positive contribution is in health and income, while its effect on educational attainment remains limited. This suggests that DBHCHT effectiveness varies across the development dimensions examined.

The control variables are positively correlated with human development. PAD and GRDP per capita positively affect HDI, indicating that stronger fiscal capacity and economic activity are associated with better welfare outcomes. This may be because high revenue generation allows for greater investment in public services, infrastructure, education, and healthcare. These findings are consistent with Jin & Jakovljevic (2023), who argue that fiscal autonomy strengthens regional development through greater expenditure flexibility. Similarly, Hung & Thanh (2022) also found that stronger economic performance leads to better human development outcomes. This is also consistent with the broader literature on the positive correlation between fiscal capacity and economic growth and human development. However, while previous studies have primarily emphasized the role of fiscal capacity and economic growth in promoting human development, this study shows that these factors complement the effects of fiscal transfer instruments. This finding highlights the importance of considering both transfer-based fiscal resources when examining human development outcomes.

The Open Unemployment Rate (TPT) shows a positive relationship with human development, defying conventional expectations in development theory. Usually, high unemployment is expected to reduce welfare because fewer people are employed. However, this is consistent with Stijepic (2021), who found that improvements in educational attainment do not automatically reduce unemployment when labor market conditions constrain the effective use of human capital. This suggests that higher human development may coexist with relatively high unemployment during periods of labor market adjustment. In Central Java, this is understandable because improvements in education may precede the expansion of formal employment. This pattern is commonly observed during structural transformation, when economic modernization generates transitional unemployment. Unemployment is positively associated with HDI in the study period because it may reflect labor market adjustment rather than worsening welfare conditions.

The robustness analysis provides more evidence on the channels through which fiscal transfers affect human development. Village Funds and DBHCHT remain key factors in explaining differences in life expectancy and per capita expenditure. This is because fiscal transfers are often used to fund healthcare services, sanitation facilities, social protection programs, and local economic development, all of which directly impact health and household welfare. This finding aligns with Suhyanto et al. (2021), who stressed the role of fiscal transfers in strengthening local public service delivery, particularly in healthcare. Similar findings were reported by Wirandana & Khoirunnofik (2022), who found that fiscal transfers boost welfare by stimulating local economic activity and strengthening

regional economic resilience. While previous studies generally evaluate welfare outcomes using aggregate indicators, the present study uses a more detailed approach by examining individual dimensions of human development. The findings suggest that fiscal transfers have a stronger effect on health and income outcomes than on educational attainment, indicating that their benefits are transmitted through distinct channels and are not uniform across all dimensions of human development.

However, the impact of both Village Funds and DBHCHT on years of schooling is not significant. This is because improvements require greater investment of time and resources. The educational outcomes are contingent upon several factors, including the level of funding allocated to the educational sector, the quality of teaching staff, the infrastructure available at educational institutions, and the socio-economic characteristics of households.

This result is similar with Yubilianto's (2020) argument that education requires continuous investment. In contrast to the more immediate impact of health and income, the process of education is characterized by a more gradual progression. This phenomenon supports the notion that fiscal transfers, while exerting a substantial influence on health and income outcomes, do not invariably translate into immediate impacts on educational attainment.

The findings support fiscal decentralization theory, as previous studies have shown that intergovernmental fiscal transfers positively impact welfare and regional development. Guerrero et al. (2022) reported similar evidence, emphasizing that vertical intergovernmental transfers are essential for supporting subnational development by enabling more effective resource allocation and financing development priorities. This suggests that fiscal transfers can contribute to better development outcomes when they are aligned with regional needs and policy objectives.

However, unlike most previous studies that rely primarily on HDI as a composite indicator, this study examines the specific dimensions of human development through robustness analysis. Results show that fiscal transfers have heterogeneous effects across welfare dimensions. Village Funds and DBHCHT are stronger contributors to health and income but have a limited effect on education. This extends the existing literature by demonstrating that the effectiveness of fiscal transfers depends on the type of transfer instrument and the development channel, thereby affecting human development regionally.

CONCLUSION

The empirical results of this study show that fiscal transfers play a significant role in improving human development in Central Java. In particular, Village Funds and DBHCHT have a positive and statistically significant effect on the HDI, indicating that intergovernmental fiscal transfers effectively contribute to human development outcomes at the district and city levels. In addition, PAD and GRDP per capita positively influence HDI. At the same time, TPT shows a positive association with HDI, reflecting structural labor-market conditions in which improvements in human capital are not immediately

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matched by employment absorption. The robustness results further show that fiscal transfers have heterogeneous effects across dimensions of human development. Village Funds and DBHCHT significantly improve life expectancy and per capita income, but do not significantly affect mean years of schooling. These findings indicate that fiscal transfers are more effective at improving health and income outcomes than at improving education outcomes, which tend to require longer-term structural investment.

This study provides several policy recommendations for the government. First, both central and local governments need to strengthen the effectiveness of the Village Funds and the DBHCHT by ensuring more targeted allocation to health services and income-generating programs where the impacts are most evident. Second, education-oriented development should be strengthened through more structured and long-term fiscal interventions, including performance-based transfer mechanisms to improve educational attainment across regions. Third, improvements in governance, transparency, and monitoring systems are necessary to ensure that fiscal transfers translate into measurable development outcomes across Central Java's districts and cities. Several limitations should also be acknowledged. This study focuses solely on HDI and its constituent indicators as proxies for human development. Future research is encouraged to incorporate broader multidimensional welfare indicators and additional institutional and socioeconomic variables to provide a more comprehensive understanding of the effectiveness of fiscal transfers in regional development.

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What Drives the Indonesian Rupiah? Evidence from VECM and Machine Learning

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ABSTRACT

Research Originality: Unlike previous studies that primarily focus on either macroeconomic determinants of exchange rates or forecasting performance separately, this study integrates both perspectives by examining exchange rate determinants and comparing conventional econometric and machine learning approaches within a single framework.

Research Objectives: This study examines the effects of inflation, interest rates, money supply, trade balance, and foreign exchange reserves on the Indonesian Rupiah exchange rate and compares the forecasting performance of VECM and machine learning models.

Research Methods: This study employs a VECM to investigate long-run and short-run relationships and compares its forecasting performance with SVR, Random Forest, and LSTM models using monthly data from 2010 to 2024.

Empirical Results: The results indicate a long-run cointegrating relationship between exchange rates and macroeconomic fundamentals. In the short run, money supply significantly affects exchange rate movements. Among the forecasting models, LSTM achieves the highest predictive accuracy based on MAE, MAPE, and RMSE.

Implications: The findings highlight the importance of macroeconomic fundamentals in maintaining exchange rate stability and demonstrate the potential of machine learning techniques, particularly LSTM, for exchange rate forecasting in Indonesia.

Keywords:
macroeconomic fundamentals; cointegration; forecasting; long short-term memory

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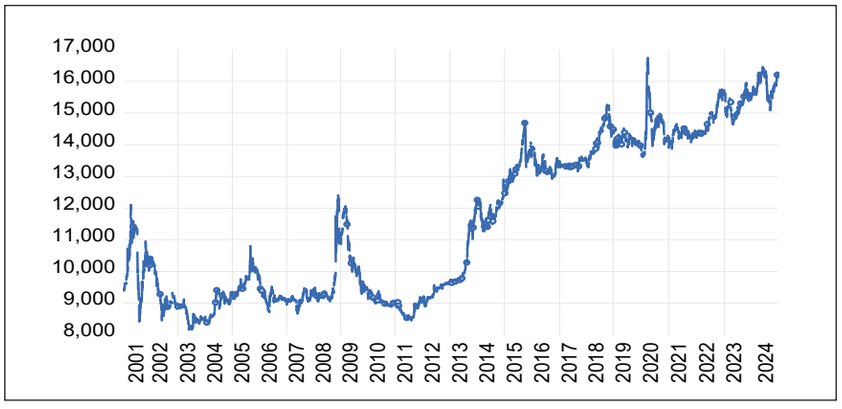
INTRODUCTION

The exchange rate is a significant indicator of a country's economic health, influencing trade competitiveness, inflation, and financial stability (Anwar et al., 2022). For Indonesia, a small open economy highly exposed to global market fluctuations, understanding exchange rate dynamics is especially important. As shown in Figure 1, the Indonesian Rupiah exhibited relative resilience from 2001 to 2010, tending to revert to its long-term level following global or regional disturbances. However, beginning in 2010, the exchange rate experienced a persistent depreciation trend. This structural shift in behavior has been influenced by several global developments, including the United States Federal Reserve's tapering announcement in 2013, the COVID-19 pandemic in 2020, and subsequent geopolitical tensions (Cristanto & Bowo, 2021). These events have triggered capital flow volatility and exposed vulnerabilities in Indonesia's external sector, thereby amplifying pressure on the exchange rate (Bank Indonesia, 2024).

Figure 1. Exchange Rate (IDR/USD) in Indonesia from January 2001–December 2024



Source: Bank Indonesia

A growing body of literature suggests that several macroeconomic variables have significant effects on exchange rate dynamics. In the Indonesian context, Carissa and Khoirudin (2020) found that money supply and trade-related variables are among the most influential factors affecting exchange rate fluctuations, whereas inflation plays a relatively minor role. Setiawan et al. (2021) reported that money supply and interest rates significantly affect the Rupiah exchange rate in the long run, while inflation and export-import variables do not exhibit significant impacts. Anwar et al. (2022) further showed that interest rates, money supply, inflation, and foreign exchange reserves influence exchange rate behavior through monetary policy transmission channels. Dewi and Fauzan (2023) also documented a long-run relationship between exchange rates and macroeconomic fundamentals using a VECM framework. While these studies provide valuable insights into the determinants of exchange rates, most focus primarily on identifying macroeconomic drivers and pay limited attention to the comparative forecasting performance of alternative analytical approaches. Moreover, existing evidence is largely based on conventional econometric

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models, leaving uncertainty regarding whether machine learning techniques can provide more accurate exchange rate forecasts in the Indonesian context.

Among conventional econometric approaches, the Vector Error Correction Model (VECM) has been widely employed to analyze exchange rate dynamics because it can capture both long-run equilibrium relationships and short-run adjustments among cointegrated macroeconomic variables (Dewi & Fauzan, 2023; Setiawan et al., 2021). VECM is particularly useful for analyzing non-stationary variables that exhibit cointegration, allowing researchers to distinguish between temporary fluctuations and long-run equilibrium movements. However, despite its strong theoretical foundation and interpretability, VECM is limited in capturing nonlinear relationships and complex interactions that frequently characterize financial and macroeconomic time series (Lin et al., 2025; Makridakis et al., 2023).

To address the limitations of conventional econometric models, recent studies have increasingly adopted machine learning approaches for exchange rate forecasting. Models such as Support Vector Regression (SVR), Random Forest, and Long Short-Term Memory (LSTM) have demonstrated promising forecasting performance by capturing nonlinear relationships and long-term dependencies in financial time series (Abouzaid & Boussedra, 2025; Ghahremani & Nguyen, 2025). Recent evidence suggests that machine learning models often outperform traditional forecasting methods, particularly during periods of heightened uncertainty and structural change (Yu et al., 2023; Tang & Xie, 2025; Reikard, 2026). Furthermore, hybrid and ensemble approaches that combine economic fundamentals with machine learning algorithms have shown significant improvements in forecasting accuracy, highlighting the growing role of artificial intelligence in financial and macroeconomic prediction (Adesina & Obokoh, 2025; Bai et al., 2026).

Despite the growing literature, several important gaps remain unresolved. First, many previous studies on Indonesia focus either on identifying macroeconomic determinants of exchange rates using conventional econometric approaches or on forecasting exchange rates using machine learning techniques. As a result, evidence that simultaneously examines exchange rate determinants and compares forecasting performance within a single analytical framework remains limited. Second, most existing studies rely on relatively short sample periods and do not fully capture major economic disruptions experienced by Indonesia between 2010 and 2024, including the taper tantrum, the COVID-19 pandemic, and the recent global monetary tightening cycle. Third, direct empirical comparisons between VECM, Support Vector Regression, Random Forest, and Long Short-Term Memory models using recent Indonesian data are still scarce.

This study addresses these gaps by integrating macroeconomic analysis and forecasting evaluation within a unified framework. The novelty of this research lies in simultaneously investigating the long-run and short-run effects of inflation, interest rates, money supply, trade balance, and foreign exchange reserves on the Indonesian Rupiah exchange rate using VECM, while comparing its forecasting performance with SVR, Random Forest, and LSTM models. Using monthly data from January 2010 to December 2024, this study provides updated evidence on exchange rate dynamics during a period characterized by

substantial economic and financial disruptions. Therefore, this research contributes not only to the literature on exchange rate determinants but also to the growing literature on machine learning-based exchange rate forecasting, offering insights for policymakers and practitioners seeking to improve exchange rate monitoring and forecasting in Indonesia.

METHODS

This study uses monthly data from January 2010 to December 2024, yielding 180 observations for each variable. The period was selected because it captures several major economic events affecting exchange rate dynamics in Indonesia, including the 2013 taper tantrum, the COVID-19 pandemic, and the post-pandemic global monetary tightening cycle. The data were obtained from Bank Indonesia (BI) and Statistics Indonesia (BPS). The dependent variable is the Indonesian Rupiah exchange rate against the United States Dollar (IDR/USD). The independent variables consist of inflation, interest rate, money supply, trade balance, and foreign exchange reserves. These variables were selected based on their theoretical relevance and empirical evidence from previous studies examining exchange rate determinants in Indonesia. Table 1 presents the operational variables used in this study.

Table 1. Operational Variables

Variables	Definitions	Measurements	Sources	References
Exchange Rate	Value of one country's currency compared to another	IDR/USD	BI	(Mankiw, 2022)
Inflation	An increase in the price level of goods and services	Percentage (%)	BPS	(Mankiw, 2022)
Interest Rate	The cost of borrowing money or the return on savings	Percentage (%)	BI	(Mankiw, 2022)
Money Supply	The total amount of money that is circulating in an economy at any point in time	Billion Rupiah (M2)	BI	(Mankiw, 2022)
Trade Balance	The difference between a nation's exports and imports	Million USD	BPS	(Mankiw, 2022)
Foreign Exchange Reserves	The foreign-currency equivalents of the central banks of nations	Million USD	BI	(Ibrahim & Sukmana, 2023)

To examine the relationship between macroeconomic variables and exchange rate dynamics, this study employs a Vector Error Correction Model (VECM). VECM is appropriate when variables are integrated of order one (I(1)) and cointegrated, allowing both long-run equilibrium relationships and short-run adjustments to be estimated simultaneously (Dewi & Fauzan, 2023; Ibrahim & Sukmana, 2023). The empirical model is specified as follows:

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$$\Delta ER_t = \alpha_0 + \sum_{i=1}^{p-1} \beta_{1i} \Delta ER_{t-i} + \sum_{i=1}^{p-1} \beta_{2i} \Delta INF_{t-i} + \sum_{i=1}^{p-1} \beta_{3i} \Delta IR_{t-i} + \sum_{i=1}^{p-1} \beta_{4i} \Delta MS_{t-i} + \sum_{i=1}^{p-1} \beta_{5i} \Delta TB_{t-i} + \sum_{i=1}^{p-1} \beta_{6i} \Delta FER_{t-i} + \gamma ECT_{t-1} + \epsilon_t \quad (1)$$

where ER denotes the exchange rate, INF represents inflation, IR denotes the interest rate, MS refers to money supply, TB represents the trade balance, FER denotes foreign exchange reserves, and ECT is the error correction term representing deviations from long-run equilibrium. The empirical analysis follows four stages. First, the Augmented Dickey-Fuller (ADF) test is employed to examine stationarity. Second, the optimal lag length is determined using information criteria. Third, the Johansen cointegration test is conducted to identify long-run relationships among the variables. Finally, the VECM is estimated to evaluate both long-run and short-run effects.

In addition to the econometric analysis, this study applies three machine learning models, namely Support Vector Regression (SVR), Random Forest, and Long Short-Term Memory (LSTM), to forecast exchange rate movements. These models are selected because they can capture nonlinear relationships and complex interactions that may not be adequately represented by conventional econometric approaches. SVR constructs a regression function by minimizing prediction errors within a predefined margin while maintaining model simplicity. Random Forest is an ensemble learning method that combines multiple decision trees to improve predictive accuracy and reduce overfitting. Meanwhile, LSTM, a type of recurrent neural network, is particularly suitable for time-series forecasting because it can capture long-term dependencies and nonlinear patterns in sequential data.

The forecasting performance of VECM, SVR, Random Forest, and LSTM is evaluated using Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), and Root Mean Square Error (RMSE). Lower values of these indicators imply better forecasting performance. The measures are defined as follows:

$$MAE = \frac{1}{n} \sum_{t=1}^{n} |y_t - \hat{y}_t| \quad (2)$$

$$MAPE = \frac{100\%}{n} \sum_{t=1}^{n} \left| \frac{y_t - \hat{y}_t}{y_t} \right| \quad (3)$$

$$RMSE = \sqrt{\frac{1}{n} \sum_{t=1}^{n} (y_t - \hat{y}_t)^2} \quad (4)$$

where y_t denotes the actual value and $\hat{y}_t$ denotes the predicted value.

RESULT AND DISCUSSION

This study examines the effects of macroeconomic fundamentals on the Indonesian Rupiah exchange rate and compares the forecasting performance of conventional econometric and machine learning approaches. The empirical results reveal three main findings. First, the exchange rate and macroeconomic variables exhibit a long-run cointegrating relationship, confirming the importance of macroeconomic fundamentals in explaining exchange rate dynamics. Second, money supply is identified as the only variable

with a significant short-run effect on exchange rate movements, while money supply, trade balance, and foreign exchange reserves significantly influence exchange rate equilibrium in the long run. Third, among the forecasting models evaluated, Long Short-Term Memory (LSTM) achieves the highest predictive accuracy, outperforming VECM, Support Vector Regression (SVR), and Random Forest. These findings highlight the continued relevance of macroeconomic fundamentals while demonstrating the potential of machine learning techniques for exchange rate forecasting in Indonesia.

Table 2. Summary Statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
Exchange Rate	180	12887.48	2324.421	8508	16421
Inflation	180	4.127	1.844	1.32	8.79
Interest Rate	180	5.692	1.251	3.5	7.75
Money Supply	180	5328838	2080837	2066481	9210816
Trade Balance	180	1307.594	1828.662	-2331.1	7558.8
Foreign Exchange Reserves	180	119610.3	17875.19	69562	155719

To provide an overview of the data characteristics, Table 2 presents the summary statistics of the variables used in this study. The average exchange rate during the observation period was IDR12,887.48 per USD, with a standard deviation of IDR2,324.42, indicating considerable fluctuations in the value of the Indonesian Rupiah. The minimum exchange rate was IDR8,508 per USD, while the maximum reached IDR16,421 per USD, reflecting substantial exchange rate movements between 2010 and 2024. Inflation averaged 4.13 percent with a standard deviation of 1.84, suggesting relatively moderate price fluctuations over the study period. Inflation ranged from 1.32 percent to 8.79 percent, reflecting periods of both low and high inflationary pressure. The average interest rate was 5.69 percent, with a standard deviation of 1.25. The minimum interest rate was 3.50 percent, while the maximum reached 7.75 percent, indicating adjustments in monetary policy in response to changing macroeconomic conditions. The money supply averaged IDR5.33 quadrillion, with a standard deviation of IDR2.08 quadrillion. The minimum value was IDR2.07 quadrillion, while the maximum reached IDR9.21 quadrillion, reflecting the continuous expansion of liquidity in the Indonesian economy throughout the observation period. Trade balance exhibited substantial variability, with an average surplus of USD1.31 billion and a standard deviation of USD1.83 billion. The minimum value of negative USD2.33 billion indicates periods of trade deficit, whereas the maximum value of USD7.56 billion reflects periods of strong export performance. Foreign exchange reserves averaged USD119.61 billion, with a standard deviation of USD17.88 billion. The lowest reserve level was USD69.56 billion, while the highest reached USD155.72 billion, indicating a steady accumulation of reserves and strengthening external sector resilience.

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Table 3. Stationary Test Results using ADF Test

Variables	Prob. Level	Prob. 1st Difference
Exchange Rate	0.7419	0.0000
Inflation	0.1819	0.0000
Interest Rate	0.3293	0.0000
Money Supply	0.9973	0.0000
Trade Balance	0.1253	0.0000
Foreign Exchange Reserves	0.2849	0.0000

Table 3 reports the results of the Augmented Dickey-Fuller (ADF) test. The findings indicate that all variables are non-stationary at level, as their probability values exceed the 5% significance level. However, after first differencing, all variables become stationary with probability values below 0.05. These results suggest that all variables are integrated of order one, I(1), satisfying the prerequisite for cointegration analysis and VECM estimation.

Table 4. Optimal Lag Selection Results

Lag	LR	FPE	AIC	HQ
0	NA	9.76×10^{25}	76.87045	76.91518
1	153.1078*	5.85×10^{25}*	76.35792*	76.67101*
2	49.44919	6.53×10^{25}	76.46600	77.04746
3	26.11442	8.41×10^{25}	76.71525	77.56508
4	34.84927	1.02×10^{26}	76.89760	78.01581
5	46.01288	1.13×10^{26}	76.98999	78.37657

The optimal lag length was determined using the Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), and Hannan-Quinn Criterion (HQ). As shown in Table 4, lag 1 is selected as the optimal lag because it maximizes LR and minimizes the FPE, AIC, and HQ criteria. Therefore, lag 1 is used in the subsequent VECM estimation.

Table 5. Johansen Cointegration Test Results using Trace Statistic

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.
None*	0.231797	108.0584	95.75366	0.0054
At most 1	0.131842	61.11946	69.81889	0.2026
At most 2	0.110548	35.95361	47.85613	0.3987
At most 3	0.044720	15.10093	29.79707	0.7735
At most 4	0.035963	6.957213	15.49471	0.5826
At most 5	0.002457	0.437936	3.841465	0.5081

The Johansen cointegration test confirms the existence of a long-run equilibrium relationship among the variables. Both the Trace Statistic and Max-Eigen Statistic reject the null hypothesis of no cointegration at the 5% significance level. The results indicate the presence of one cointegrating equation, suggesting that exchange rates and macroeconomic fundamentals move together in the long run. Therefore, the use of VECM is appropriate for capturing both long-run equilibrium and short-run adjustments.

Table 6. Johansen Cointegration Test Results using Max-Eigen Statistic

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.
None*	0.231797	46.93893	40.07757	0.0073
At most 1	0.131842	25.16585	33.87687	0.3739
At most 2	0.110548	20.85268	27.58434	0.2852
At most 3	0.044720	8.143716	21.13162	0.8947
At most 4	0.035963	6.519277	14.26460	0.5475
At most 5	0.002457	0.437936	3.841465	0.5081

Table 7 presents the short-run VECM estimation results. Money supply is the only macroeconomic variable that significantly affects exchange rate movements. The coefficient of money supply is negative and statistically significant, indicating that increases in liquidity are associated with Rupiah appreciation, although the magnitude of the effect remains relatively small. This finding highlights the importance of monetary conditions in influencing short-term exchange rate dynamics and is consistent with previous studies that identified money supply as a key determinant of exchange rate movements in Indonesia (Setiawan et al., 2021; Anwar et al., 2022). Similar evidence has also been documented in emerging economies, where changes in domestic liquidity conditions influence exchange rates through portfolio adjustments, inflation expectations, and capital flow responses (Ibrahim & Sukmana, 2023).

Table 7. VECM Estimation Results (Short-Run)

	Coefficient	Std. Error
ΔER_{t-1}	-0.332*	0.082
ΔINF_{t-1}	27.624	49.924
ΔIR_{t-1}	-20.370	166.214
ΔMS_{t-1}	-0.001*	0.000
ΔTB_{t-1}	-0.040	0.025
ΔFER_{t-1}	0.015	0.001
ECT_{t-1}	-0.233*	0.064
F-Statistic	10.9062	
R-Square	0.31117	

Note:* significant at 5%

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The lagged exchange rate variable exhibits a significant negative coefficient, suggesting a self-correcting mechanism in which exchange rate shocks gradually dissipate over time. Furthermore, the error correction term is negative and statistically significant, indicating that approximately 23.3 percent of any deviation from long-run equilibrium is corrected within one period. This result confirms the stability of the long-run relationship among the variables and supports the suitability of the VECM framework for analyzing exchange rate dynamics. Inflation, interest rates, trade balance, and foreign exchange reserves do not exhibit statistically significant short-run effects. Although their estimated coefficients generally conform to theoretical expectations, the findings suggest that short-term exchange rate fluctuations are driven primarily by liquidity conditions rather than by inflationary pressures or external sector variables. This result is broadly consistent with Carissa and Khoirudin (2020), who reported that monetary variables tend to exert stronger short-run influences on exchange rates than external sector indicators.

In the long run, money supply, trade balance, and foreign exchange reserves are found to significantly influence exchange rate equilibrium. The significance of money supply indicates that monetary conditions play an important role in shaping exchange rate dynamics over time. This finding supports previous evidence that expansion in domestic liquidity can affect exchange rate behavior through inflation expectations, capital flows, and monetary transmission mechanisms (Setiawan et al., 2021; Anwar et al., 2022).

Table 8. VECM Estimation Results (Long-Run)

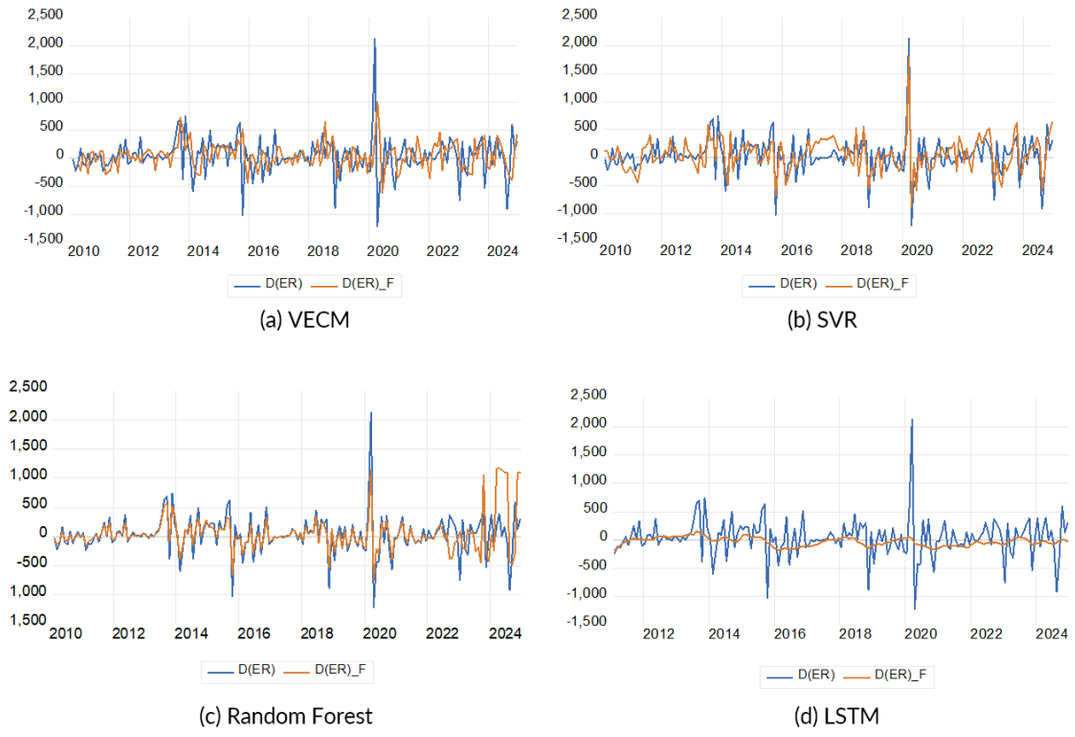
	Coefficient	Std. Error
INF	29.139	82.296
IR	-373.460	213.202
MS	-0.002*	0.001
TB	-0.645*	0.047
FER	0.061*	0.014

Note:* significant at 5%

The significance of trade balance highlights the importance of export performance and external sector strength in supporting exchange rate stability. A stronger trade balance increases foreign currency earnings and contributes to a more stable exchange rate environment. Similarly, foreign exchange reserves play an important role in maintaining market confidence and reducing vulnerability to external shocks. These findings are consistent with Carissa and Khoirudin (2020), Dewi and Fauzan (2023), and Ibrahim and Sukmana (2023), who also identified external sector fundamentals as important determinants of exchange rate movements in Indonesia and other emerging economies. The long-run significance of money supply, trade balance, and foreign exchange reserves suggests that both monetary and external sector fundamentals continue to play a central role in determining the value of the Indonesian Rupiah. This finding underscores the

importance of policy coordination between monetary authorities and external sector management in preserving exchange rate stability amid changing global economic conditions.

Figure 2. Forecasting Values of Exchange Rate (*Difference*) for All Models



(a) VECM (b) SVR

(c) Random Forest (d) LSTM

Source: author's calculation

As a complement to the econometric analysis, this study evaluates the forecasting performance of selected machine learning techniques. Figure 2 and Table 9 compare the forecasting performance of VECM, Support Vector Regression (SVR), Random Forest, and Long Short-Term Memory (LSTM). The results indicate that LSTM achieves the highest forecasting accuracy, recording the lowest MAE (254.44), MAPE (322.29), and RMSE (174.27) among all models. These findings suggest that deep learning approaches are more effective in capturing the complex and nonlinear behavior of exchange rate movements than conventional econometric models. Among the remaining models, VECM ranks second and performs substantially better than both Random Forest and SVR. This result indicates that macroeconomic fundamentals continue to provide valuable information for exchange rate forecasting, particularly when long-run equilibrium relationships exist among variables.

Random Forest exhibits moderate forecasting performance, while SVR produces the largest forecasting errors and ranks last among the evaluated models. The relatively weaker performance of SVR may indicate that exchange rate dynamics during the sample period were characterized by structural changes and nonlinear interactions that the selected model specification could not adequately capture. In contrast, LSTM can learn complex

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temporal dependencies and adapt to changing data patterns, which may explain its superior forecasting performance.

Table 9. Forecasting Performance Comparison Across Models

Model	MAE	MAPE	RMSE
VECM	273.77	424.04	403.37
SVR	1,769.92	4,137.00	1,912.77
Random Forest	445.92	1,050.11	572.13
LSTM	254.44	322.29	174.27

The strong performance of LSTM may be particularly relevant in the Indonesian context, where exchange rate movements are frequently influenced by external shocks, policy adjustments, and changing global financial conditions. Such circumstances generate nonlinear dynamics that are often difficult to capture using conventional linear econometric approaches. These findings are consistent with recent studies highlighting the advantages of deep learning techniques in financial and macroeconomic forecasting (Yu et al., 2024; Tang & Xie, 2025; Li et al., 2026). At the same time, the relatively strong performance of VECM suggests that economically interpretable models remain valuable for policy analysis and for understanding the transmission mechanisms linking macroeconomic fundamentals and exchange rate movements (Ibrahim & Sukmana, 2023).

CONCLUSION

This study examines the effects of inflation, interest rates, money supply, trade balance, and foreign exchange reserves on the Indonesian Rupiah exchange rate and evaluates the forecasting performance of conventional econometric and machine learning approaches using monthly data from 2010 to 2024. The results confirm the existence of a long-run equilibrium relationship between exchange rates and macroeconomic fundamentals. In the short run, money supply is the only variable that significantly influences exchange rate movements, whereas money supply, trade balance, and foreign exchange reserves are significant determinants of exchange rate equilibrium in the long run. The forecasting analysis further reveals that Long Short-Term Memory (LSTM) achieves the highest predictive accuracy among the evaluated models, outperforming VECM, Support Vector Regression (SVR), and Random Forest. These findings indicate that macroeconomic fundamentals remain important in explaining exchange rate dynamics while machine learning techniques offer substantial improvements in forecasting performance.

The findings imply that maintaining sound monetary conditions and a strong external sector is essential for supporting exchange rate stability in Indonesia. In particular, appropriate liquidity management, sustainable trade performance, and adequate foreign exchange reserve accumulation can strengthen resilience against external shocks and exchange rate volatility. In addition, policymakers may benefit from incorporating machine learning

techniques, particularly LSTM, into forecasting frameworks to complement conventional econometric approaches and improve the accuracy of exchange rate projections. Future policy formulation may therefore benefit from combining economic fundamentals with data-driven forecasting tools to support more effective macroeconomic decision-making.

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Corporate Sukuk Issuance and Firm Fundamentals: A Dynamic Causality Approach from Indonesia

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ABSTRACT

Research Originality: This study extends existing knowledge on corporate sukuk by moving beyond static determinant frameworks and examining the dynamic relationships between firm fundamentals and issuance behavior. The analysis offers new insights into the factors underlying sustained access to Sharia-compliant financing.

Research Objectives: This study investigates whether financial performance, capital structure, firm size, and asset growth predict the issuance behavior of Indonesian sukuk issuers.

Research Methods: Using quarterly panel data from the five most active issuers during 2015Q1-2024Q4, this study applies panel Granger causality and panel VAR with impulse response and variance decomposition.

Empirical Results: The findings reveal that firm size Granger-causes sukuk issuance, whereas return on equity, net profit margin, capital structure, and asset growth do not show Granger-causal effects at conventional levels. Issuance also exhibits strong persistence and responds more strongly to firm-size shocks than to other firm fundamentals.

Implications: These results suggest that policies to deepen the sukuk market should reduce issuance frictions, improve disclosure quality, and expand access to Sharia-compliant financing for mid-sized firms.

Keywords:

Islamic capital market; Sharia-compliant financing; panel Granger causality; panel VAR; financial fundamentals

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INTRODUCTION

The financial sector in Indonesia plays a strategic role in supporting national and regional economic growth through both conventional and Sharia-based financial systems. As a Muslim-majority country, Indonesia has substantial potential to strengthen Islamic finance through Sharia-compliant instruments that support ethical investment, financial diversification, and alternative corporate financing. In this context, sukuk have emerged as a key Islamic capital market instrument because they link investors with asset-based financing and provide firms with access to medium- and long-term funding (Suriani et al., 2021; Balli et al., 2022; Mseddi, 2023; Almaskati, 2022). Therefore, the expansion of Islamic financial instruments is not only relevant for religious compliance but also for strengthening financial inclusion, investment diversification, and long-term economic development.

Despite the growing need for investment and financing instruments, the development of alternative Sharia-compliant securities remains important for broadening market participation and reducing dependence on conventional financing channels. Sukuk provide an alternative investment and financing instrument because they combine Sharia compliance, asset-based structure, and portfolio diversification benefits (Balli et al., 2022; Pirgaip et al., 2021; Saeed et al., 2021). The development of Islamic financial institutions has also encouraged the expansion of the Islamic capital market, which has become one of the most important segments of Islamic finance in Indonesia. In this context, the development of the sukuk market is closely related to macro-financial stability, institutional support, and monetary policy transmission (Suriani et al., 2021; Aman et al., 2021; Aziz et al., 2021). At the market level, sukuk development is also influenced by the strength of the financial system, macroeconomic conditions, and institutional support, which makes market deepening important for expanding domestic sukuk activity (Aman et al., 2021).

Within the Islamic capital market, sukuk serve a strategic function by mobilizing investor capital and channeling it into productive corporate financing. Sukuk differ from conventional bonds because they require underlying assets and must comply with Sharia principles, including the prohibition of riba, gharar, and maysir, as regulated through DSN-MUI fatwas and relevant financial market regulations (DSN-MUI, 2004; Suriani et al., 2021). Previous studies have shown that sukuk contribute to capital market deepening, support long-term economic growth, and provide diversification benefits for investors (Balli et al., 2022; Pirgaip et al., 2021; Yıldırım et al., 2020). Corporate sukuk, in particular, are important because they connect public investors with non-bank corporate financing and provide medium- to long-term funding for companies that require capital for business expansion and strategic projects (Ashraf et al., 2021; Almaskati, 2022; Mseddi, 2023; Endri et al., 2022).

However, the development of corporate sukuk in Indonesia remains less dominant than sovereign sukuk, even though corporate sukuk were introduced earlier in the market. This condition indicates that the corporate sukuk segment still faces structural constraints, including issuer readiness, market access, information asymmetry, disclosure quality, sukuk risk management, and issuance costs (Aman et al., 2021; Aziz et al., 2021; Setiawan &

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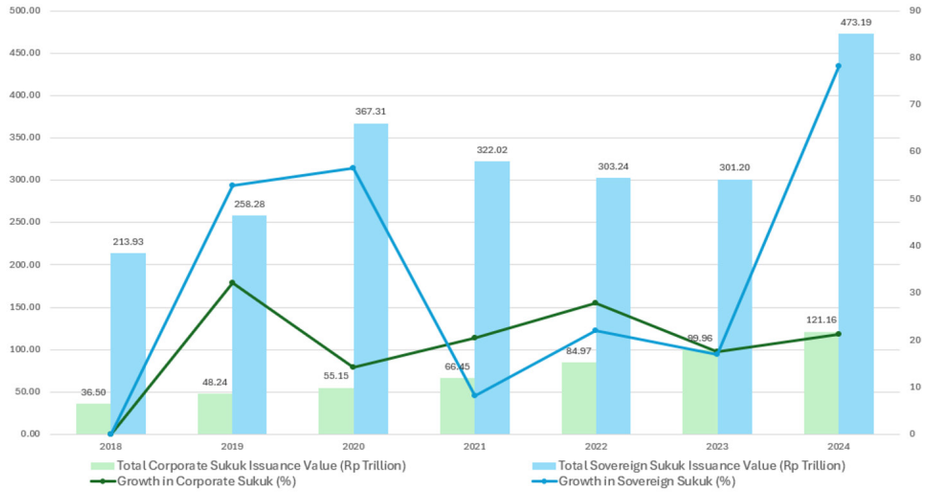
Suwandaru, 2024; OJK, 2024). Investor trust is also relevant in sukuk transactions because sukuk activity is sensitive to information asymmetry, issuer risk, and market confidence (Aziz et al., 2021). Corporate sukuk are also more exposed to issuer-specific risk, liquidity constraints, and market uncertainty than sovereign sukuk, and these risks may be reflected in pricing, yield spreads, and investor assessment of issuer quality (Saeed et al., 2021; Almaskati, 2022, 2023; Mseddi, 2023; Billah et al., 2024). As a result, firms with stronger financial and institutional capacity are generally more likely to access this market successfully. Hence, understanding the firm-level factors that shape corporate sukuk issuance is necessary to explain why some firms issue sukuk more actively while others remain constrained.

Figure 1. Total and Growth Sukuk of Sovereign and Corporate Issuance



Source: Author's calculation based on OJK Sukuk Statistics, 2018-2024

Several prior studies have examined sukuk from different perspectives. At the market level, Suriani et al. (2021) and Aman et al. (2021) show that sukuk development is closely related to macro-financial conditions, monetary policy transmission, and institutional support. Other studies examine sukuk risk, liquidity, yield spread, market connectedness, and investor confidence, showing that issuer risk, liquidity conditions, and market uncertainty influence sukuk performance (Aziz et al., 2021; Saeed et al., 2021; Almaskati, 2022, 2023; Mseddi, 2023; Billah et al., 2024; Mensi et al., 2024). At the firm level, previous research has focused on sukuk ratings, issuer characteristics, and the choice between sukuk and conventional bonds (Al Homsi et al., 2023; Laila et al., 2021; Wardiwiyono & Imron, 2022; Ashraf et al., 2021; Pribadi & Wibowo, 2019). However, these studies mostly use macroeconomic, rating, market reaction, or static determinant approaches. Limited evidence explains whether firm fundamentals dynamically predict corporate sukuk issuance over time.

From the corporate perspective, internal fundamentals are expected to influence the feasibility, timing, and scale of sukuk issuance. Financial performance reflects the firm's ability to generate profits and maintain its repayment capacity, which may shape investor confidence

and access to funding. Return on Equity and Net Profit Margin represent profitability and operating efficiency, and stronger financial performance may reduce perceived issuer risk and improve market confidence in corporate financing decisions (Saeed et al., 2021; Laila et al., 2021; Khan & Qasem, 2024). Capital Structure reflects the balance between debt and equity and determines whether a firm has sufficient capacity to absorb additional financing without increasing financial distress risk. Firms with more prudent leverage are generally better positioned to access external financing and maintain investor confidence (Rehan et al., 2023; Ferriswara et al., 2022; Khan & Qasem, 2024). Firm Size is also relevant because larger firms generally have stronger reputation, wider market access, better disclosure capacity, and more mature governance mechanisms, which may reduce information asymmetry and issuance costs (Al Homsi et al., 2023; Laila et al., 2021; Wardiwiyono & Imron, 2022). In addition, Assets Growth reflects business expansion and financing needs, especially when firms require medium- or long-term funds that are compatible with the underlying asset structure of sukuk. Asset expansion can create financing demand, but the decision to issue sukuk also depends on issuer readiness, governance, and market access (Pribadi & Wibowo, 2019; Ashraf et al., 2021; Rehan et al., 2023).

Based on these considerations, this topic remains important because Indonesia's corporate sukuk market is still less developed than its sovereign sukuk market, limiting firms' access to Sharia-compliant long-term financing. Although previous studies have examined sukuk from macroeconomic, rating, market reaction, and static determinant perspectives, limited evidence explains how firm-level fundamentals dynamically predict and respond to corporate sukuk issuance over time. This study fills that gap by applying Panel Granger causality, PVAR, impulse response, and variance decomposition to examine the dynamic relationship between Financial Performance, Capital Structure, Firm Size, Asset Growth, and corporate sukuk issuance among active Indonesian issuers during 2015Q1-2024Q4. The novelty lies in showing not only causal direction but also persistence and shock-response mechanisms, particularly the dominant role of firm size. The findings are expected to support regulators, issuers, and investors in strengthening a more inclusive corporate sukuk market in Indonesia.

METHODS

This study uses a quantitative approach to examine the dynamic relationship between firm-level fundamentals and corporate sukuk issuance in Indonesia. The analysis focuses on corporate sukuk issuers registered with the Financial Services Authority (OJK). The observation period covers 2015Q1 to 2024Q4. This period was selected for three main reasons. First, the period provides a sufficiently long quarterly observation window to capture the development of corporate sukuk issuance after the strengthening of Islamic capital market regulation in Indonesia. Second, the 2015Q1-2024Q4 period allows the study to observe corporate sukuk issuance dynamics before, during, and after major economic shocks, including the COVID-19 pandemic, which may affect firms' financing behavior. Third, data availability during this period is relatively consistent across active corporate sukuk issuers, allowing the construction of a balanced quarterly panel dataset.

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The population of this study consists of 45 corporate sukuk issuers registered with OJK. The sample was selected using purposive sampling based on several criteria. First, the company must be registered as a corporate sukuk issuer during the 2015Q1-2024Q4 observation period. Second, the company must have published financial reports or financial statements that are available and accessible during the observation period. Third, the company must be included among the most active corporate sukuk issuers to ensure sufficient variation in issuance behavior. Based on these criteria, five companies were selected as the final sample, namely PT Adira Dinamika Multi Finance Tbk, PT Aneka Gas Industri Tbk, PT Indosat Tbk, PT Perusahaan Listrik Negara (Persero), and PT XL Axiata Tbk. The panel data consist of five firms observed quarterly for 40 quarters, resulting in 200 firm-quarter observations.

Table 1. Operational Variables

Variables	Definitions	Measurements	Sources
LSIV	The value of corporate sukuk issued by each firm	Natural logarithm of sukuk issuance value	OJK and company reports
ROE	Firm ability to generate profit from shareholders' equity	Net income divided by total equity	Financial statements
NPM	Firm ability to convert sales into net income	Net income divided by sales	Financial statements
CS	Firm financing composition between debt and equity	Debt-to-Equity Ratio	Financial statements
LFS	Scale of company operations	Natural logarithm of total assets	Financial statements
AG	Change in firm assets over time	Year-over-year change in total assets	Financial statements

Source: Processed data (2026)

This study employs Panel Granger causality and Panel Vector Autoregressive (PVAR) models as the main analytical tools. Panel Granger causality is used to test whether past values of financial performance, capital structure, firm size, and asset growth help predict corporate sukuk issuance beyond its own past values (Granger, 1969). The PVAR model is then applied to capture dynamic interdependence among variables, where each variable can be influenced by its own lagged values and the lagged values of other variables in the system (Love & Zicchino, 2006; Lütkepohl, 2005).

Before estimating the dynamic model, this study conducts panel unit root tests to ensure the stationarity of the data. The Im, Pesaran, and Shin (IPS) test and the Phillips-Perron (PP) Fisher-type test are used to examine whether the variables contain a unit root (Im et al., 2003; Phillips & Perron, 1988). Stationarity testing is important because non-stationary data may produce biased or spurious estimation results in autoregressive time-series and dynamic panel analysis (Lütkepohl, 2005). After the stationarity properties are confirmed, the optimal lag length is determined using standard information criteria,

including LR, FPE, AIC, SC, and HQ. The selected lag length is then used in the Panel Granger causality test and PVAR estimation to ensure consistency across the empirical analysis. The empirical model in this study is specified as follows:

Model 1: Panel Granger Causality Model

$$LSIV_{it} = \alpha_i + \sum_{j=1}^{p} \beta_j LSIV_{i,t-j} + \sum_{j=1}^{p} \gamma_j ROE_{i,t-j} + \sum_{j=1}^{p} \delta_j NPM_{i,t-j} + \sum_{j=1}^{p} \theta_j CS_{i,t-j} + \sum_{j=1}^{p} \lambda_j LFS_{i,t-j} + \sum_{j=1}^{p} \phi_j AG_{i,t-j} + \varepsilon_{it} \quad (1)$$

where $LSIV_{it}$ denotes the logarithm of corporate sukuk issuance value for firm i at time t. ROE_{it} represents return on equity, NPM_{it} represents net profit margin, CS_{it} represents capital structure, LFS_it represents the logarithm of firm size, and AG_{it} represents asset growth. The term α_i captures firm-specific effects, p denotes the optimal lag length, j denotes the lag order, and ε_{it} is the error term. This model allows the study to test whether past movements in firm fundamentals contain useful information for predicting future corporate sukuk issuance.

Model 2: Panel Vector Autoregressive Model

$$Y_{it} = \alpha_i + \sum_{j=1}^{p} A_j Y_{i,t-j} + \varepsilon_{it} \quad (2)$$

where Y_{it} is a vector of endogenous variables consisting of *LSIV, ROE, NPM, CS, LFS,* and *AG*. In this specification, α_i represents firm-specific effects, A_j represents the coefficient matrix at lag j, p denotes the selected optimal lag length, and ε_{it} is the error term. This model treats all variables as endogenous, allowing the study to capture the dynamic interdependence between corporate sukuk issuance and firm fundamentals rather than assuming a one-way static relationship.

After estimating the PVAR model, this study applies Impulse Response Function (IRF) and Forecast Error Variance Decomposition (FEVD). IRF is used to trace how corporate sukuk issuance responds to shocks in financial performance, capital structure, firm size, and asset growth over future periods. FEVD is used to identify the relative contribution of each variable's shock to variations in corporate sukuk issuance. Therefore, the combination of Panel Granger Causality, PVAR, IRF, and FEVD provides a more comprehensive framework for explaining the dynamic behavior of corporate sukuk issuance in Indonesia during the 2015Q1-2024Q4 period.

RESULTS AND DISCUSSION

The empirical results show three main findings. First, Firm Size is the only firm-level fundamental that significantly Granger-causes corporate sukuk issuance. Second, ROE, NPM, Capital Structure, and Asset Growth do not significantly predict sukuk issuance. Third, the PVAR results show that sukuk issuance is highly persistent and mainly driven by its own past movements. These findings indicate that corporate sukuk issuance in Indonesia is more closely related to issuer scale and market readiness than to short-term profitability, leverage, or asset expansion.

Table 2 presents the descriptive statistics of Sukuk Issuance Value, Return on Equity,

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Net Profit Margin, Capital Structure, Firm Size, and Asset Growth. The panel consists of 200 firm-quarter observations from five active corporate sukuk issuers during 2015Q1-2024Q4. Sukuk Issuance Value averages 1.80 trillion, with a standard deviation of 1.65 trillion, indicating variation in issuance values across firms and quarters. The descriptive results show heterogeneous financial characteristics across active corporate sukuk issuers. This heterogeneity is relevant because sukuk issuance requires issuer credibility, disclosure capacity, and sufficient underlying assets. Larger firms generally have stronger institutional capacity, broader market access, better disclosure quality, and lower information asymmetry, which may support their ability to issue sukuk (Al Homsi et al., 2023; Laila et al., 2021; Wardiwiyono & Imron, 2022).

Table 2. Summary Statistics

Variables	Mean	Std. Dev.	Min	Max	Observations
SIV	1.80	1.65	0.07	6.68	N = 200
ROE	4.1275	8.7978	-17.1800	66.5900	
NPM	5.6312	7.5685	-15.1700	31.9500	
CS	201.2679	129.0121	43.3180	607.6300	
FS	327.00	581.00	3.49	1,720.00	
AG	1.6960	9.2511	-29.6100	72.0500	

Source: Processed data (2026)

Before estimating the dynamic model, this study conducted panel unit root tests using the Im, Pesaran, and Shin test and the Phillips-Perron test. The results show that all variables are stationary at level. LSIV, ROE, NPM, CS, LFS, and AG reject the unit-root null hypothesis, meaning that the variables can be treated as I(0). This result supports the use of Panel Granger causality and PVAR estimation in levels without requiring a cointegration framework.

Table 3. Panel Unit Root Test Results

Variables	Im-Pesaran and Shin (IPS)	Phillips-Perron (PP)
	I(0)	I(0)
LSIV	0.0000***	0.0000***
ROE	0.0000***	0.0000***
NPM	0.0000***	0.0000***
CS	0.0490**	0.0006***
LFS	0.0009**	0.0021***
AG	0.0000***	0.0000***

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

The stationarity result is important because non-stationary variables may produce misleading inferences in dynamic econometric analysis (Lütkepohl, 2005). Since all variables are stationary, the relationship between corporate sukuk issuance and firm fundamentals can be examined directly without differencing the variables (see Table 3). This helps preserve the economic interpretation of firm-level dynamics. After confirming stationarity, the optimal lag length was selected using standard information criteria, including LR, FPE, AIC, SC, and HQ. The results indicate that SC and HQ support lag 2, while LR, FPE, and AIC suggest higher lag orders. This study follows the HQ criterion and uses two lags for the Panel Granger causality and PVAR estimation (see Table 4).

Table 4. Lag Length Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-3326.096	NA	1.39e+09	38.08110	38.18960	38.12511
1	-2116.337	2322.737	2079.123	24.66671	25.42626	24.97480
2	-2016.029	185.7139	998.3832	23.93175	25.34234*	24.50393*
3	-1984.271	56.61847	1051.673	23.98024	26.04188	24.81650
4	-1936.551	81.80665	925.9676	23.84629	26.55897	24.94663
5	-1886.476	82.40897*	796.9880*	23.68544*	27.04915	25.04986

Note: The sign (*) is the optimum lag based on the criteria

The use of two lags is appropriate for quarterly panel data because it captures short-run dynamic adjustment while maintaining model parsimony. This is important because corporate financing decisions may not respond immediately to changes in profitability, leverage, firm size, or asset growth. Firms may require time to evaluate market conditions, prepare issuance documentation, and meet Sharia-compliant issuance requirements.

Panel Granger causality tests were conducted to assess whether past values of one variable improve the prediction of another variable beyond its own history (Granger, 1969). The tests use an F/Wald framework to evaluate the joint significance of lagged regressors in each equation. The Panel Granger causality results (Table 5 and Figure 3) show that Firm Size significantly Granger-causes corporate sukuk issuance at the 1 percent level. This indicates that past values of Firm Size contain useful information for predicting future corporate sukuk issuance. In contrast, ROE, NPM, Capital Structure, and Asset Growth do not significantly Granger-cause corporate sukuk issuance. These findings suggest that sukuk issuance among active Indonesian issuers is more strongly shaped by firm scale than by short-term changes in profitability, leverage, or growth.

This finding supports the view that larger firms have stronger reputational capital, broader investor access, better disclosure capacity, and greater ability to bear issuance costs. This result is consistent with Al Homsi et al. (2023), Laila et al. (2021), and Wardiwiyono and Imron (2022), who show that issuer-level characteristics influence sukuk ratings and investor assessment. This result also supports Ashraf et al. (2021) and Utami

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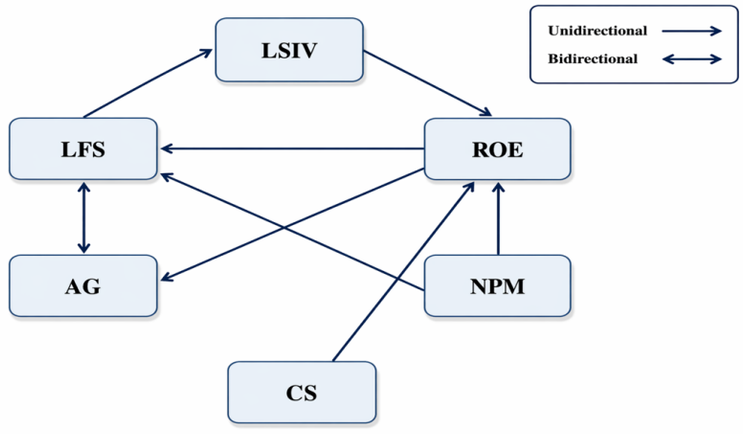
(2025), who emphasize that firm characteristics and governance affect sukuk issuance decisions. However, this study extends previous evidence by showing that Firm Size has dynamic predictive power over corporate sukuk issuance, not merely a static association.

Table 5. Panel Granger Causality Test Results

Causality Direction	F-Statistic	Prob.	Causality Direction	F-Statistic	Prob.
Causality					
LSIV → ROE	2.57448	0.0789*	ROE → AG	5.91691	0.0032***
LFS → LSIV	5.54759	0.0046***	NPM → LFS	2.38419	0.0950*
NPM → ROE	6.67443	0.0016***	AG → LFS	13.08480	0.0000***
CS → ROE	4.11258	0.0179**	LFS → AG	19.11640	0.0000***
ROE → LFS	5.86346	0.0034***	**Total significant directions**		**9**
No Causality					
ROE → LSIV	1.07485	0.3435	ROE → CS	1.89406	0.1534
NPM → LSIV	0.67600	0.5099	CS → NPM	0.86699	0.4219
LSIV → NPM	1.76040	0.1748	NPM → CS	0.97100	0.3806
CS → LSIV	1.15986	0.3158	LFS → NPM	0.73063	0.4830
LSIV → CS	0.37626	0.6869	AG → NPM	0.42523	0.6543
LSIV → LFS	0.13212	0.8763	NPM → AG	2.11661	0.1233
AG → LSIV	0.52826	0.5905	LFS → CS	0.17158	0.8425
LSIV → AG	0.07117	0.9313	CS → LFS	0.13156	0.8768
ROE → NPM	0.06160	0.9403	AG → CS	0.31064	0.7334
LFS → ROE	0.90731	0.4054	CS → AG	0.16569	0.8474
AG → ROE	0.71696	0.4896	**Total non-significant directions**		21

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Figure 3. Panel Granger Causality Results



Source: author's compilation (2026)

The insignificant effects of ROE and NPM indicate that stronger profitability does not automatically lead firms to issue sukuk. Profitable firms may rely on internal funding, while sukuk issuance requires additional considerations such as asset availability, disclosure quality, Sharia compliance, issuance costs, and market timing. Capital Structure also does not significantly predict sukuk issuance, suggesting that leverage conditions alone are not sufficient to explain issuance behavior. Similarly, Asset Growth does not significantly Granger-cause sukuk issuance, implying that expansion does not necessarily translate into sukuk financing. These results indicate that corporate sukuk issuance depends more on issuer scale and market readiness than on short-term financial indicators. This interpretation is consistent with sukuk market studies showing that issuance and performance are shaped not only by firm fundamentals, but also by liquidity, market connectedness, and risk transmission across financial markets (Almaskati, 2023; Billah et al., 2024; Mensi et al., 2024).

The PVAR estimation strengthens the Panel Granger causality results. The Impulse Response Function shows that an own shock to corporate sukuk issuance generates a persistent positive response (see Figure 4). This indicates that sukuk issuance exhibits strong path dependence, meaning that firms with prior issuance experience are more likely to maintain access to the sukuk market in subsequent periods. This persistence may reflect investor familiarity, accumulated market experience, and lower repeated issuance costs.

The response of corporate sukuk issuance to Firm Size shocks also becomes positive after the initial adjustment. This result indicates that larger firms are more capable of accessing the corporate sukuk market because they generally have stronger asset bases, better financial capacity, and higher credibility among investors. These characteristics help firms meet the structural and regulatory requirements of sukuk issuance, particularly because sukuk is closely related to asset-based or asset-backed financing mechanisms. Larger firms also tend to have better readiness in preparing documentation, disclosure, and investor communication. This interpretation is consistent with studies showing that sukuk issuance depends on issuer characteristics, governance readiness, asset capacity, and market credibility (Ashraf et al., 2021; Almaskati, 2022; Mseddi, 2023).

By contrast, shocks to ROE and NPM are followed by negative responses in corporate sukuk issuance. This suggests that unexpected profitability improvements do not necessarily encourage firms to issue sukuk. One possible explanation is that firms with stronger profitability may have more internal funds and less immediate need for external financing. Shocks to Capital Structure generate a temporary positive response, but the effect gradually declines. Meanwhile, Asset Growth shocks produce a temporary negative response that fades over time, indicating that expansion alone does not guarantee sukuk issuance unless supported by sufficient scale, credible disclosure, and financing readiness.

The Forecast Error Variance Decomposition results show that corporate sukuk issuance is mostly explained by its own shocks. In period 1, all variation in LSIV is

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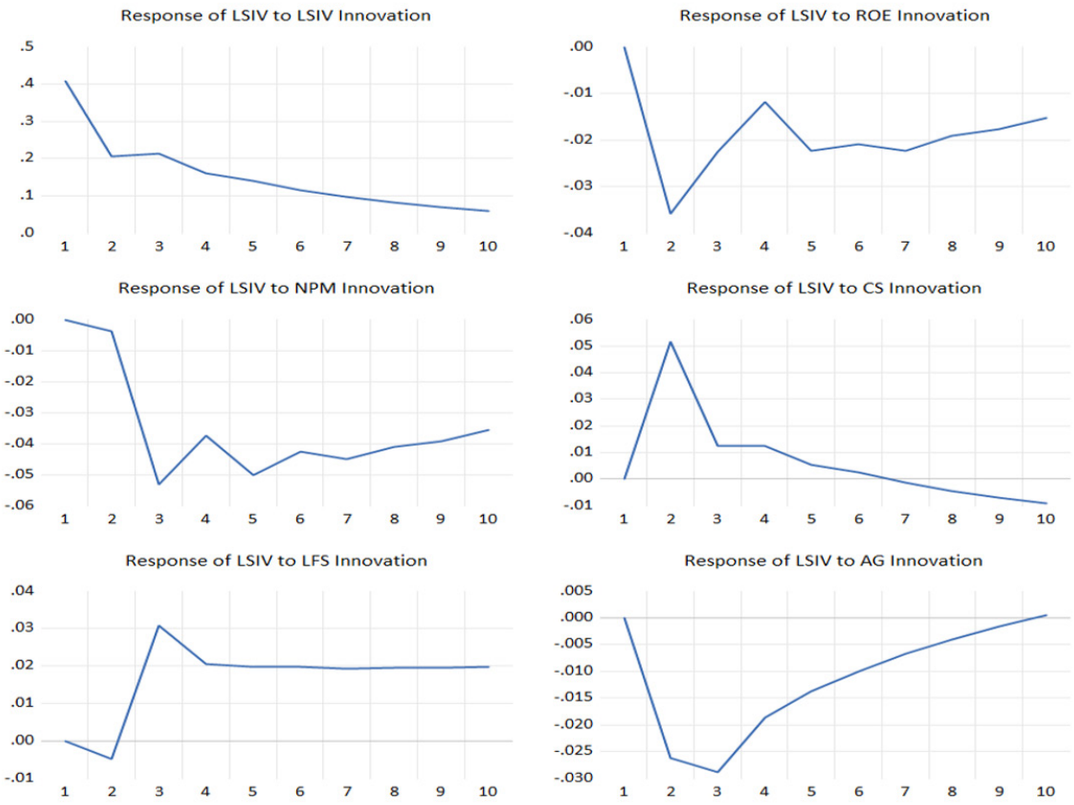
explained by its own innovation. By period 10, LSIV still explains 92.2224 percent of its own forecast error variance. This confirms that corporate sukuk issuance among active issuers is highly persistent and self-driven.

Figure 4. IRF: LSIV Responses to Shocks in ROE, NPM, CS, LFS, and AG



Source: Processed data (2026)

Table 6. Forecast Error Variance Decomposition (Periods 1, 5, and 10)

Period	S.E.	LSIV	ROE	NPM	CS	LFS	AG
			FEVD OF LSIV				
1	0.406874	100.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.561593	94.9065	0.7707	2.1421	0.9601	0.5664	0.6543
10	0.605030	92.2224	1.1668	4.1216	0.8703	1.0103	0.6084

Source: Processed data (2026)

Table 6 also shows that the contribution of firm fundamentals to LSIV variation remains relatively limited. By the tenth period, the largest external contribution comes from NPM at 4.1216 percent, followed by ROE at 1.1668 percent, LFS at 1.0103 percent, CS at 0.8703 percent, and AG at 0.6084 percent. These results suggest that short-run variations in firm fundamentals account for only a small portion of fluctuations

in corporate sukuk issuance. However, Firm Size remains empirically important because it is the only firm-level variable that significantly Granger-causes corporate sukuk issuance. Therefore, the FEVD result should be interpreted alongside the Panel Granger causality evidence: sukuk issuance is largely self-driven, whereas firm scale provides the strongest directional signal for future issuance behavior.

Overall, the empirical results show that corporate sukuk issuance in Indonesia is a scale-sensitive financing decision. Firm Size is the only firm fundamental that significantly predicts corporate sukuk issuance, whereas profitability, capital structure, and asset growth do not have significant predictive power. This finding suggests that access to the corporate sukuk market is more strongly determined by issuer scale, asset base, disclosure capacity, and market reputation than by short-term financial indicators. This result complements previous studies on sukuk and Islamic capital markets. Many determinants of financial market effects and sukuk development include macro-financial conditions, monetary policy transmission, firm fundamentals, and institutional support (Suhendar & Suriani, 2025; Suriani et al., 2018, 2021, 2024). Aman et al. (2021) emphasize the role of trust and market confidence in sukuk activity, as do Aziz et al. (2021). In contrast, this study provides firm-level dynamic evidence that issuer scale is a key predictor of corporate sukuk issuance. The findings also extend Al Homsi et al. (2023), Laila et al. (2021), Wardiwiyono and Imron (2022), Ashraf et al. (2021), and Utami (2025), which highlight issuer characteristics, sukuk ratings, governance, and financing decisions, by showing that Firm Size not only matters for issuer assessment but also predicts the continuity of sukuk issuance over time.

The insignificant effects of ROE, NPM, Capital Structure, and Asset Growth indicate that corporate sukuk issuance should not be understood merely as a response to profitability, leverage adjustment, or business expansion. Instead, sukuk issuance requires broader issuer readiness, including sufficient asset base, credible reporting, regulatory compliance, and investor confidence. From a policy perspective, this implies that efforts to deepen Indonesia's corporate sukuk market should focus on reducing issuance barriers for mid-sized firms by improving disclosure standards, lowering fixed issuance costs, broadening investor participation, and strengthening pipelines of eligible issuers. This policy direction is consistent with evidence that sukuk market development depends on institutional support, investor confidence, liquidity, and financial risk conditions (Aman et al., 2021; Aziz et al., 2021; Almaskati, 2023; Mohd Roslen et al., 2025).

CONCLUSION

Corporate sukuk issuance in Indonesia during the 2015Q1- 2024Q4 period is mainly shaped by firm scale and issuance persistence. The Panel Granger causality results show that Firm Size significantly predicts corporate sukuk issuance. At the same time, Return on Equity, Net Profit Margin, Capital Structure, and Asset Growth do not have significant predictive effects. The PVAR results also indicate that sukuk issuance

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is largely driven by its own past movements, meaning that firms with previous issuance experience tend to maintain stronger access to the sukuk market. These findings confirm that corporate sukuk issuance is not primarily determined by short-term profitability, leverage, or asset expansion, but by issuers' structural capacity, particularly firm size, asset base, disclosure capability, and market credibility. Therefore, the Indonesian Government and financial market authorities should strengthen a more inclusive corporate sukuk market by reducing issuance barriers for mid-sized firms, simplifying issuance procedures without weakening Sharia compliance, improving disclosure standards, and expanding investor participation. Corporate issuers should also integrate sukuk into long-term financing strategies supported by strong asset quality, credible reporting, and prudent capital structures. These measures are expected to expand corporate sukuk issuance beyond large repeat issuers and support the long-term development of Indonesia's Islamic capital market.

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Spatial Distribution and Cluster Analysis of Zakat Allocation: Identifying Hotspots and Coldspots

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ABSTRACT

Research Originality: This study applies spatial autocorrelation to assess the efficiency of zakat distribution, highlighting hotspot–coldspot patterns and proposing a spatially aligned framework to reduce regional disparities and support inclusive development.

Research Objectives: This study analyzes the spatial patterns of zakat distribution and their implications for distribution efficiency and reducing regional inequality.

Research Methods: Spatial autocorrelation analysis was conducted using Moran's I, Local Indicators of Spatial Association (LISA), and Getis–Ord Gi* to identify spatial linkages among regions.

Empirical Results: The results indicate significant spatial clustering in zakat distribution, with hotspots concentrated in urban and economic centers due to strong institutional capacity, while coldspots are found in remote areas with high poverty and weak institutions, potentially reinforcing spatial inequality.

Implications: These findings emphasize the importance of spatial mapping as the basis for region-based zakat distribution. Overall, zakat has the potential to become a strategic instrument for reducing inequality and driving inclusive economic development if it is integrated into evidence-based regional development policies.

Keywords:
zakat distribution; spatial mapping; clustering; regional patterns.

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INTRODUCTION

Spatial mapping of zakat recipients and poverty clusters has become an important approach to improving the accuracy and effectiveness of zakat distribution and social protection programs by identifying vulnerable groups based on geographic and socio-economic conditions rather than relying solely on administrative boundaries. Through spatial analysis methods such as Moran's I and Local Indicators of Spatial Association (LISA), researchers and policymakers can detect poverty concentration, regional disparities, and the socio-economic interconnections between neighboring areas, thereby providing a deeper understanding of poverty patterns and helping reduce targeting errors, overlap of assistance, and exclusion of eligible beneficiaries. Consequently, poverty mapping enables more precise, efficient, and equitable interventions across regions (Li, Luo, & Wu, 2026; Sholihin et al., 2024; Ru, Tennant, Matteson, & Barrett, 2026).

Mapping zakat distribution through spatial analysis not only improves targeting accuracy but also helps reduce regional inequality by identifying over- and underserved areas, enabling zakat funds to be distributed more proportionally to disadvantaged, remote, and structurally poor regions while encouraging cross-regional redistribution. Spatial mapping provides an evidence-based foundation for policymakers and zakat institutions to optimize social support programs, strengthen equitable development, and position zakat as an instrument of spatial equity that complements government fiscal and social policies (Kanbur & Venables, 2005; OECD, 2019). Furthermore, spatial mapping supports the planning of productive zakat programs by identifying regional economic potentials such as MSMEs, agriculture, and livestock, thereby transforming zakat from consumptive assistance into a sustainable economic empowerment instrument that can increase the income and independence of poor households (Barrientos, 2012; Banerjee et al., 2015).

From a governance perspective, the integration of spatial data in zakat management enhances efficiency, transparency, and accountability by optimizing distribution logistics, reducing operational costs, and enabling systematic monitoring, which in turn strengthens public and muzaki trust in zakat institutions through data-driven decision-making (Gupta, Keen, Shah, & Verdier, 2017). Furthermore, integrating zakat mapping with national social registries such as DTKS and DTSEN supports stronger coordination between zakat distribution and government social protection programs, including PKH, PIP, BPNT, and BLT, thereby reducing overlap, minimizing inclusion and exclusion errors, and improving targeting accuracy for vulnerable households (The SMERU Research Institute, 2022). Through cross-sector collaboration and harmonized data systems, zakat can function as a complementary policy instrument that addresses gaps in state interventions and strengthens the overall effectiveness of poverty alleviation and social protection programs (Kuntjorowati, Andari, Soegiharto, & Yuniarti, 2024).

Spatial analysis using methods such as Moran's I and LISA enables policymakers to identify hotspots, coldspots, and spatial clustering in zakat distribution and poverty, thereby improving the precision of geographically targeted interventions and evidence-based resource allocation (Chen et al., 2022; Li et al., 2023). In West Java, spatial

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analysis is particularly important due to significant regional disparities, where metropolitan areas such as Greater Bandung, Bodebek, and Karawang possess high zakat potential. In contrast, regions such as Garut, Tasikmalaya, Cianjur, and Pangandaran continue to experience structural poverty and limited public services. Spatial mapping helps prevent excessive concentration of zakat in urban areas, encourages spillover effects toward poorer neighboring regions, and improves the integration of zakat with government social protection systems through data integration with DTKS and Dapodik.

A place-based zakat policy approach is needed because each district and city in West Java has different socio-economic conditions and mustahik characteristics, making spatial analysis essential for designing locally tailored productive zakat programs such as agricultural, MSME, and educational assistance. In addition, hotspot–coldspot mapping and indicators such as Moran's I and LISA strengthen monitoring, evaluation, transparency, and accountability in zakat management, enabling BAZNAS and local governments to improve targeting, reduce regional inequality, and enhance zakat's role as a redistribution instrument for poverty alleviation, inclusive growth, and sustainable regional development (Karim et al., 2020; Pratama, 2023; Arbi et al., 2024).

Spatial analysis using methods such as Global Moran's I and LISA is essential in West Java to identify spatial mismatches between zakat sources and poverty pockets, enabling zakat institutions to design more equitable, efficient, and evidence-based distribution policies. Without aligning zakat distribution with the spatial concentration of poverty, zakat funds tend to remain concentrated in economically advanced areas, limiting spillover effects to poorer regions and weakening zakat's role as an instrument for welfare redistribution, poverty reduction, and regional equality. Research shows that spatially inaccurate zakat distribution has only a limited impact on reducing poverty and improving welfare, as reflected in the CIBEST Model, indicating that the effectiveness of zakat depends not only on the amount distributed but also on the spatial accuracy of its allocation (Beik, 2016).

Zakat distribution that is not aligned with poverty maps risks reducing its effectiveness in reaching poor areas, weakening its multiplier effect on regional development, increasing regional inequality, and potentially creating new pockets of poverty in West Java (Karim, 2020). Therefore, spatial analysis methods such as Global Moran's I and LISA are essential for identifying disparities between zakat collection and poverty concentrations, enabling more targeted, equitable, and data-driven distribution policies. Spatial-based zakat mapping also improves targeting accuracy, supports cross-regional redistribution from urban to rural areas, and strengthens productive zakat planning by identifying regions with economic potential for MSMEs, agriculture, and livestock development, thereby transforming zakat into a sustainable economic empowerment instrument. In addition, integrating spatial data into zakat governance enhances efficiency, transparency, accountability, and systematic monitoring, ultimately strengthening public and muzaki trust in zakat institutions.

METHODS

This study uses data on the distribution of productive and consumptive zakat across 26 cities and districts in West Java province during 2018–2023, drawn from the zakat distribution reports of BAZNAS cities/districts in West Java province. Notably, the COVID19 pandemic significantly influenced zakat distribution patterns, as its economic and social impacts increased both the demand for zakat and the volume of funds distributed. Consequently, a larger number of recipients, particularly among vulnerable populations, received zakat support, resulting in more pronounced spatial clustering in certain cities and districts in West Java. This phenomenon underscores the importance of analyzing temporal changes in zakat distribution alongside external shocks, such as pandemics, which can alter both the intensity and geographic concentration of aid.

This study employs Global Moran's I to examine spatial autocorrelation in zakat distribution across cities and districts in West Java Province. Spatial autocorrelation analysis is important for identifying whether neighboring regions exhibit similar or different zakat distribution patterns, thereby providing insights into the effectiveness and equity of zakat allocation in supporting inclusive economic growth and social welfare. Positive spatial autocorrelation indicates that nearby regions tend to have similar zakat characteristics and form clusters, while negative autocorrelation reflects dispersed and contrasting patterns. Moran's I, with values ranging from −1 to 1, is widely used to detect spatial clustering and randomness, where positive values indicate clustering, negative values indicate dispersion, and values close to zero suggest no significant spatial pattern. To confirm the existence of spatial autocorrelation, a significance test of Moran's I is conducted.

In spatial analysis, methods such as Local Indicators of Spatial Association (LISA) and the Getis–Ord Gi* statistic are widely used to identify localized clustering patterns, spatial heterogeneity, and regional disparities in socio-economic phenomena, including zakat distribution, by detecting statistically significant hotspots and coldspots based on spatial autocorrelation, z-scores, and p-values (Baeza-Gonzalez & Kamakura, 2025; Zhang et al., 2024; Wu et al., 2022; Bhunia et al., 2024). Zakat distribution hotspots represent High–High spatial clusters where areas with high zakat allocation are surrounded by neighboring regions with similarly high values, often occurring in economically active urban centers, although excessive concentration may create regional inequality (Belay et al., 2024; Bouchair & Chabbi-Chemrouk, 2020). Conversely, coldspots indicate Low–Low spatial clusters characterized by persistently low zakat distribution in underserved regions, highlighting areas that require prioritized interventions and more equitable allocation of social assistance and financial resources to improve the effectiveness of zakat and social protection policies (Bhunia et al., 2020; Kanbur & Venables, 2005; Arbia & Nardelli, 2024).

RESULTS AND DISCUSSION

Spatial autocorrelation analysis is an important tool for evaluating the efficiency, equity, and socio-economic impact of zakat distribution because it reveals how zakat allocation in one region is spatially related to neighboring areas, thereby identifying

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patterns of clustering, regional inequality, and interregional dependency. Positive spatial autocorrelation or high–high clusters may indicate that zakat funds are concentrated in geographically connected regions. At the same time, other areas with similar poverty levels or mustahik needs remain underserved, reflecting weaknesses in the distribution system caused by limited beneficiary data, unequal institutional capacity, or location bias. By understanding these spatial patterns, zakat institutions can optimize resources through integrated area-based programs such as productive zakat and community-based MSME development, which can reduce distribution costs, strengthen economic spillover effects, and improve local economic activity, purchasing power, and social stability through regional synergies and economies of scale. However, if zakat clusters remain concentrated only in certain urban areas, zakat may unintentionally reinforce spatial inequality and weaken its role in promoting inclusive economic growth.

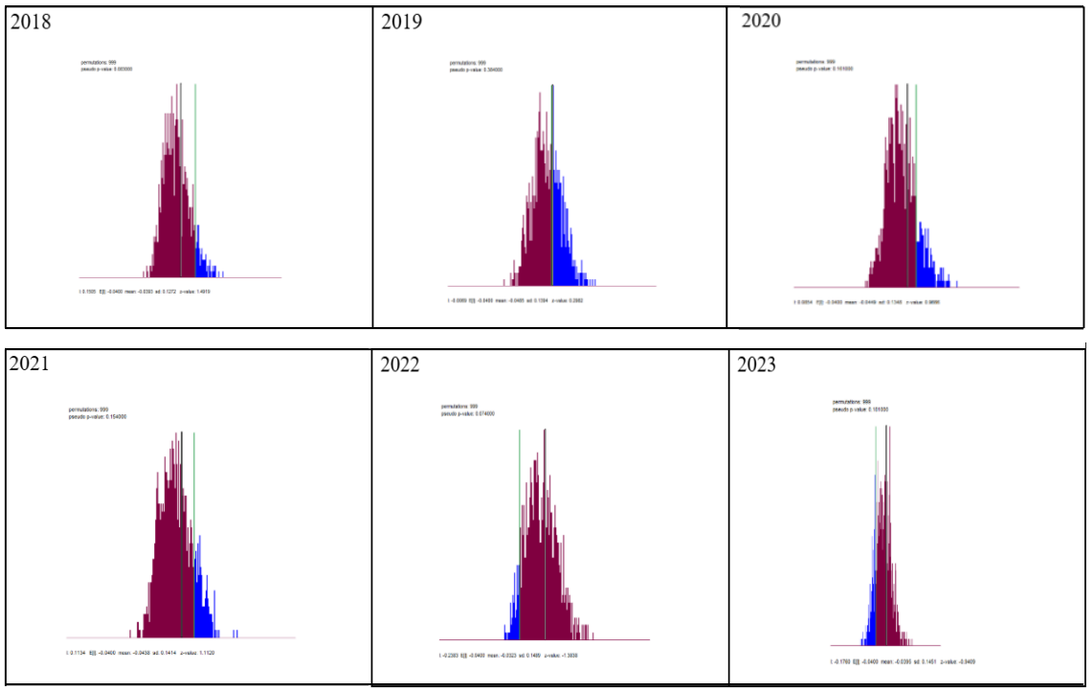
Within the context of inclusive and sustainable regional development, zakat has substantial potential as an Islamic social finance instrument for reducing poverty and regional inequality when integrated with public policy, social protection, education, and economic empowerment programs. However, empirical findings in West Java during 2018–2023 show Moran's Index values close to zero, indicating that zakat distribution patterns remain relatively random and are not yet systematically aligned with spatial poverty concentrations, thereby limiting the effectiveness of targeted and integrated interventions (Beik & Arsyianti, 2016; Karim et al., 2020; Bhunia et al., 2024). The absence of strong and stable spatial clustering also reflects weak socio-economic integration and limited spillover effects between regions with high and low zakat capacity, suggesting that the current zakat distribution system remains spatially uncoordinated and may contribute to widening regional welfare disparities. Therefore, stronger spatial analysis, interregional collaboration, institutional integration, and coordination between zakat institutions and local governments are needed to transform zakat into a more equitable and effective instrument for inclusive and sustainable regional development (Campos et al., 2024; Fitriani et al., 2026; Arbia & Nardelli, 2024).

Figure 1 shows the results of the Global Moran's I analysis, which indicate the presence or absence of spatial autocorrelation in the distribution of zakat funds across cities/districts in West Java Province.

Moran's Index values close to zero during the 2018–2023 period indicate that zakat distribution in West Java generally lacked strong and statistically significant spatial autocorrelation, meaning that zakat allocation across regions tended to be relatively random at the provincial level. However, annual analysis reveals dynamic spatial tendencies, where weak positive autocorrelation emerged in 2020–2021, suggesting limited local clustering of regions with similar high zakat values, while negative Moran values in 2018, 2019, 2022, and 2023 reflected spatial contrasts and local anomalies between neighboring regions with high and low zakat distributions. These differences may have influenced temporal variations in distribution policies, regional economic conditions, data reporting quality, and the presence of zakat collection center outliers. Therefore, complementary spatial analyses such as LISA, spatial weight matrix sensitivity testing, and outlier detection are

needed to identify local hotspots and support more targeted, evidence-based, and effective zakat redistribution policies.

Figure 1. Global Moran's I Analysis Result



The COVID-19 pandemic temporarily altered the spatial distribution of zakat in West Java during 2020–2021 by increasing localized poverty and shifting zakat priorities toward emergency assistance in regions most affected by economic disruption, job losses, and mobility restrictions, leading to weak positive spatial autocorrelation around major zakat collection centers and pandemic-affected areas. However, the weak and statistically insignificant Moran's I values indicate that these changes were only short-term adjustments rather than permanent structural transformations in zakat distribution patterns. Spatial fluctuations were also influenced by regional socio-economic disparities, where urban and industrial areas such as Bandung, Bekasi, and Depok experienced stronger zakat collection during post-pandemic recovery. In contrast, agrarian regions such as Indramayu, Tasikmalaya, and Garut remained dependent on small-scale consumptive zakat. These conditions created inconsistent spatial patterns and highlighted the absence of strong integration between urban zakat potential and rural mustahik needs. Therefore, spatially informed policies, including interregional zakat redistribution mechanisms, integrated zakat information systems, and localized spatial analyses such as LISA, are essential for developing evidence-based and geographically targeted interventions that strengthen zakat's role in reducing regional inequality, promoting economic empowerment, and supporting inclusive and sustainable development (Pratomo & Rahman, 2021; BAZNAS, 2022; Bhunia et al., 2024; Fitriani et al., 2026; Arbia & Nardelli, 2024).

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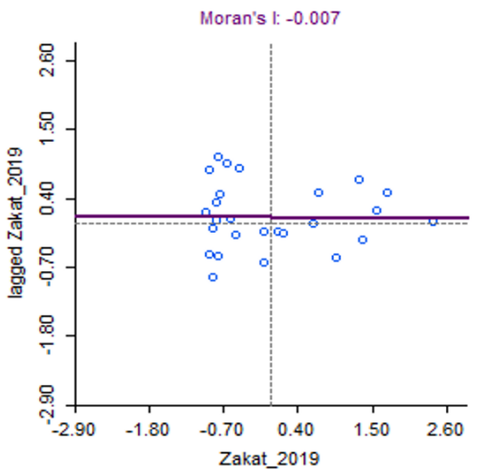
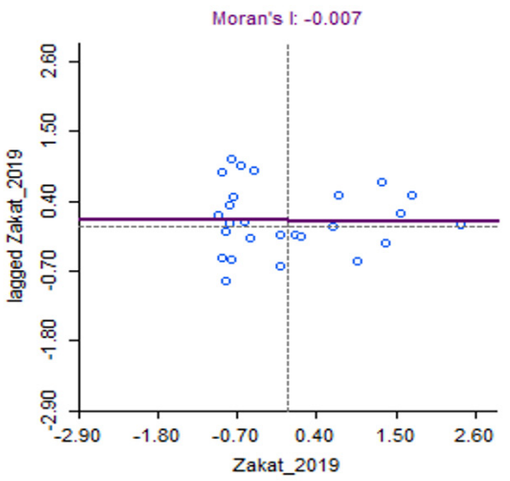
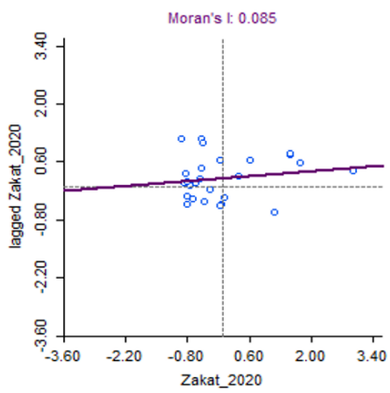
The results of Global Moran's I testing on inter-city/district zakat in West Java Province show positive spatial autocorrelation. This is evident in Moran's I index, which yielded values between 0 and 1. It can be seen that zakat has Global Moran's I values of 0.1041, 0.1179, 0.1073, and 0.1138 over the four years of observation. Although the values obtained are not identical, the differences are not significant. It can be seen that the four years still obtained a Moran's I index of 0.1.

Shifts in Moran's Index values in West Java during 2018–2023 were influenced not only by institutional factors but also by regional socio-economic conditions, where industrial and urban areas such as Bandung, Bekasi, and Depok experienced increased zakat collection alongside post-pandemic economic recovery, while agrarian and poorer regions such as Indramayu, Tasikmalaya, and Garut continued to depend mainly on small-scale consumptive zakat. These differences caused spatial patterns to fluctuate from weak positive clusters during 2020–2021 to more dispersed and contradictory patterns in later years, particularly in 2023 when zakat distribution became more focused on emergency response and economic recovery needs.

Figure 2. Scatter Plot Hotspot and Coldspot

Scatter-Plot	
2018	2019
	
HH Ciamis, Kuningan, Sumedang	HH Bandung, Ciamis, Indramayu, Kuningan, Subang, Sumedang
HL Bandung, West Bandung, Bandung City, Subang, Sukabumi	HL Cianjur, Karawang, Bandung City, Sukabumi
LH Bekasi, Cirebon, Garut, Indramayu, Banjar City, Cimahi City, Cirebon City, Depok City, Majalengka	LH Bekasi, Cirebon, Garut, Banjar City, Depok City, Sukabumi City, Tasikmalaya City, Majalengka, Purwakarta
LL Bogor, Cianjur, Karawang, Bekasi City, Bogor City, Sukabumi City, Tasikmalaya City, Purwakarta, Tasikmalaya	LL West Bandung, Bogor, Bekasi City, Bogor City, Cimahi City, Cirebon City, Tasikmalaya

2020



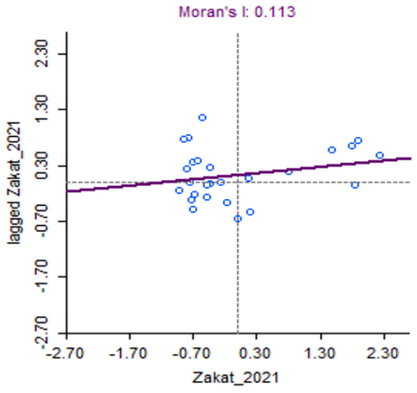
HH
Bandung, Ciamis, Indramayu, Subang, Sumedang

HL
Cianjur, KotBandung, Sukabumi

LH
Bekasi, Cirebon, Garut, Banjar City, Cimahi City, Cirebon City, Depok City, Sukabumi City, Tasikmalaya City, Kuningan, Majalengka

LL
West Bandung, Bogor, Karawang, Bekasi City, Bogor City, Purwakarta, Tasikmalaya

2021



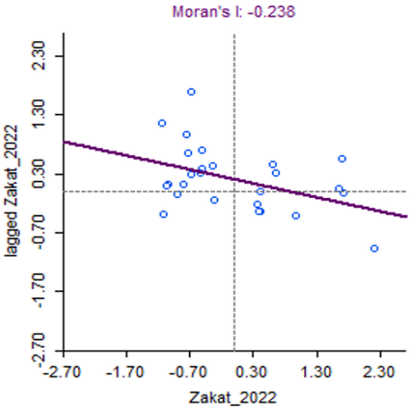
HH
Bandung, Ciamis, Subang, Sumedang

HL
Cianjur, Indramayu, Bandung City, Bekasi City, Sukabumi

LH
Bekasi, Cirebon, Garut, Banjar City, Depok City, Sukabumi City, Tasikmalaya City, Majalengka

LL
Wset Bandung, Bogor, Karawang, Bogor City, Cimahi City, Cirebon City, Kuningan, Purwakarta, Tasikmalaya

2022



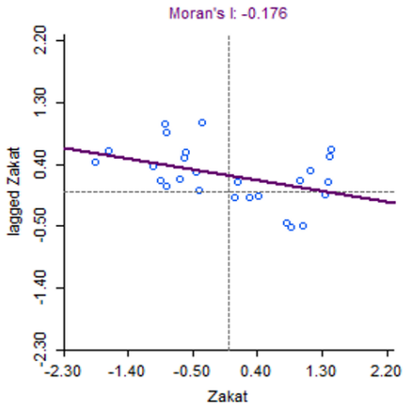
HH
Indramayu, KotBekasi, Sukabumi, Tasikmalaya

HL
Bekasi, Bogor, Ciamis, Cianjur, Cirebon, Bandung City, Sumedang

LH
Garut, Bogor City, Tasikmalaya City, Kuningan, Purwakarta

LL
Bandung, West Bandung, Karawang, Banjar City, Cimahi City, Cirebon City, Depok City, Sukabumi City, Majalengka, Subang

2023



HH
Indramayu, Bekasi City, Sukabumi, Tasikmalaya

HL
Bekasi, Bogor, Ciamis, Cianjur, Cirebon, Bandung City, Sumedang

LH
Garut, Bogor City, Tasikmalaya City, Kuningan, Purwakarta

LL
Bandung, West Bandung, Karawang, Banjar City, Cimahi City, Cirebon City, Depok, Sukabumi City, Majalengka, Subang

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Overall, these dynamics indicate that zakat collection and distribution in West Java remain strongly influenced by annual policy priorities, regional economic disparities, and differences in institutional capacity, resulting in a lack of spatial consistency between urban zakat potential and rural mustahik needs. Therefore, spatial-based policies such as interregional zakat redistribution mechanisms and integrated provincial zakat information systems are needed to ensure that zakat distribution is both socially fair and geographically equitable (Pratomo & Rahman, 2021; BAZNAS, 2022).

Ciamis, Kuningan, and Sumedang are classified as High–High clusters in the LISA analysis because they possess strong and innovative zakat institutions, productive community economic structures, and strong socio-economic and religious connectivity, particularly through Islamic boarding school networks and Islamic economic activities, which create positive spatial spillover effects in zakat distribution across neighboring regions (Karim et al., 2020). In contrast, Bandung City, Bandung Regency, West Bandung Regency, Subang, and Sukabumi fall into the High–Low category, indicating that these economically developed urban areas have high zakat collection values but are surrounded by neighboring regions with relatively low zakat capacity, reflecting local negative spatial autocorrelation and spatial inequality in zakat distribution. This pattern suggests that zakat resources remain concentrated in urban economic centers and have not been optimally redistributed to surrounding poorer regions, highlighting the need for stronger interregional zakat redistribution mechanisms, expansion of zakat institution networks, and integrated cross-district zakat management to strengthen zakat's role as an instrument of spatial equity and inclusive economic development.

The LISA analysis identifies Bekasi, Cirebon, Garut, Indramayu, Majalengka, Banjar City, Cimahi City, Cirebon City, and Depok City as belonging to the Low–High (LH) category, meaning these regions have relatively low zakat collection or distribution values despite being surrounded by areas with high zakat capacity, indicating local negative spatial autocorrelation and spatial inequality in zakat distribution (LeSage & Pace, 2009). Economically, this pattern reflects that some areas with strong economic activity, such as Bekasi and Depok, still experience limited formal philanthropic participation due to low zakat literacy and weak local zakat institutions. In contrast, regions near major zakat and Islamic economic centers like Greater Bandung have not fully optimized their zakat potential (Huda & Sawarjuwono, 2019). Nevertheless, the existence of spatial dependence suggests that these low-potential regions could benefit from neighboring high-capacity areas through stronger redistribution mechanisms and institutional collaboration (Amalia & Pratama, 2020).

These findings support the study of Pratomo and Rahman (2021), which explains that Low–High (LH) areas in West Java function as potential mustahik regions requiring cross-regional zakat redistribution policies, reflecting the concentration of zakat collection in urban centers such as Bandung, Bogor, and Purwakarta while surrounding regions primarily act as beneficiaries. This urban-centric zakat distribution pattern may reinforce spatial inequality in zakat benefits across regions (Hassan et al., 2022), highlighting the need for integrated interregional zakat management systems, expansion of LAZ/UPZ units, strengthening of

digital zakat networks, and improved public literacy on Islamic economics and formal zakat payment in line with RPJMN 2020–2024 and BAZNAS recommendations. In addition, LISA analysis identifies several regions, including Bogor, Cianjur, Karawang, Purwakarta, Tasikmalaya, Bekasi City, Bogor City, Sukabumi City, and Tasikmalaya City, as Low–Low (LL) clusters characterised by low zakat collection surrounded by neighbouring regions with similarly low values, indicating localized spatial disparities and structural inequalities that reinforce the importance of spatial analysis for designing more targeted, equitable, and inclusive zakat policies (Baeza-Gonzalez & Kamakura, 2025; Arbia & Nardelli, 2024; Zhang et al., 2024; Wu et al., 2022; Bhunia et al., 2024).

The Low–Low spatial pattern in zakat distribution in West Java reflects clusters of poverty and weak zakat institutional capacity in regions characterized by low to medium economic activity, dominance of agricultural and informal sectors, limited Islamic financial infrastructure, weak zakat literacy, and low formal zakat collection. Although some regions such as Bogor have strong macroeconomic conditions, formal zakat collection remains limited due to preferences for informal philanthropy. In contrast, regions such as Cianjur, Karawang, Purwakarta, Tasikmalaya, and Sukabumi depend largely on agriculture, small trade, and home industries, resulting in lower zakat values compared to metropolitan areas like Bandung and Bekasi (Amalia & Pratama, 2020). This condition creates a "zakat deficit zone" in southern and central West Java. It highlights the need for structural and institutional interventions, including strengthening Zakat Collection Units (UPZ) at local levels, expanding zakat institution coverage, improving zakat literacy and digitisation, and enhancing interregional redistribution collaboration between High–Low (HL) and Low–High (LH) areas to reduce regional inequality and promote more equitable zakat distribution in line with the RPJMN 2020–2024 agenda (Hassan et al., 2022; Huda & Sawarjuwono, 2019; Pratomo & Rahman, 2021; Bappenas, 2021).

The spatial autocorrelation analysis of zakat distribution reveals significant hotspot and coldspot patterns influenced not only by regional poverty levels and economic potential but also by the fragmented, independent institutional structure of regional zakat agencies (BAZDA) in Indonesia. Strong zakat collection centers, particularly in urban economic regions, tend to redistribute funds within their own administrative areas, reinforcing spatial concentration and inequality, while coldspot areas characterized by structural poverty, remoteness, and weak institutional capacity remain underserved and dependent on limited local zakat resources (Karim et al., 2020). The absence of integrated interregional zakat redistribution mechanisms further strengthens unequal spatial dependency patterns, causing hotspot regions to dominate the zakat network. At the same time, coldspot areas remain trapped in persistent low-resource conditions, thereby limiting zakat's effectiveness in reducing poverty and improving welfare (Beik & Arsyianti, 2016). Consequently, significant policy reforms are needed, including stronger coordination by central BAZNAS, integrated national zakat data systems, and evidence-based spatial redistribution policies to improve institutional integration, close regional distribution gaps, and strengthen zakat's role as an instrument for equitable welfare distribution and inclusive economic development.

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CONCLUSION

Spatial analysis methods Moran's I, LISA, and Getis–Ord Gi* are important tools for identifying geographical interdependencies, spatial autocorrelation, and hotspot–coldspot patterns in zakat distribution. Hotspots generally emerge in urban economic centers with strong zakat institutions and high collection capacity, while coldspots are commonly associated with structurally poor, remote, and institutionally weak regions. These spatial patterns reflect the degree of socio-economic integration and interregional dependency, where hotspot areas generate multiplier and spillover effects through increased economic activity. In contrast, coldspot areas indicate structural isolation, weak institutional connectivity, and persistent regional inequality. Spatial clustering analysis also shows that regions with strong zakat capacity often influence neighboring areas, while regions with weak spatial interaction tend to remain trapped in low–low clusters. Therefore, mapping zakat hotspots and coldspots provides an important evidence-based foundation for integrating zakat with social protection and regional development policies to promote inclusive and sustainable economic growth.

Based on these findings, several policy recommendations can be proposed to improve the effectiveness, equity, and inclusiveness of zakat allocation across regions. Zakat institutions should prioritize coldspot areas through geographically targeted distribution strategies, while hotspot regions should focus on strengthening productive zakat and economic empowerment programs rather than merely increasing allocations. Stronger interregional coordination, integrated zakat management systems, and alignment between zakat distribution and regional poverty conditions are also necessary to reduce spatial mismatches and improve redistribution efficiency. In addition, integrating zakat with broader social protection, financial inclusion, and regional development policies, alongside strengthening GIS-based analytics, digital infrastructure, institutional capacity, and governance, is essential for supporting evidence-based policymaking and more effective spatially informed zakat distribution.

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Microenterprise Sustainability in Islamic Microfinance

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ABSTRACT

Research Originality: This study fills a gap in prior research by jointly examining Islamic financial literacy, intellectual capital, and working capital in Baznas Microfinance Desa and by testing financial performance as the mechanism through which these factors sustain microenterprises.

Research Objectives: This study analyzes the determinants of microenterprise sustainability among Baznas Microfinance Desa partners in East Java, Indonesia.

Research Methods: Using a quantitative explanatory design, data were collected from 285 respondents through five-point Likert-scale questionnaires and analyzed with PLS-SEM.

Empirical Results: Islamic financial literacy, intellectual capital, and working capital significantly enhance financial performance and microenterprise sustainability. Working capital shows the strongest contribution, while financial performance has the largest direct effect on sustainability and significantly mediates the relationships between the three determinants and sustainability.

Implications: Islamic microfinance programs should prioritize working-capital management while strengthening Islamic financial literacy and capability-oriented mentoring to build intellectual capital, as these factors improve financial performance and, in turn, sustain microenterprises.

Keywords:
baznas microfinance desa; business continuity; financial performance; intellectual capital; Islamic financial literacy; working capital

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INTRODUCTION

Microenterprise sustainability remains an important issue because microenterprises face structural constraints that differ from those of larger firms. Compared with larger businesses, they often operate with limited financial buffers, weaker managerial systems, and restricted access to formal finance. As a result, even modest shocks can disrupt liquidity, weaken financial performance, and threaten business continuity. In this context, sustainability refers to the ability of a business to maintain operations, adapt to change, and preserve performance over time (Gorondutse et al., 2020; Kurniasari et al., 2023; AlQershi et al., 2023). For this reason, the issue remains highly relevant, particularly in empowerment-based financing ecosystems.

This study focuses on beneficiaries of Baznas Microfinance Desa, a non-profit Islamic microfinance program funded through zakat mal and infaq and distributed to *mustahik*. Unlike conventional microfinance institutions, Baznas Microfinance Desa emphasizes empowerment rather than profit generation by providing productive business capital and business assistance. In this setting, business continuity is closely linked to economic empowerment because sustainable operations help beneficiaries maintain liquidity discipline, meet repayment commitments, and gradually strengthen their economic independence. Accordingly, examining sustainability in Baznas Microfinance Desa is important not only from a business perspective but also from the perspective of empowerment-oriented Islamic microfinance.

Previous studies suggest that several factors shape business continuity. Islamic financial literacy helps microentrepreneurs make Sharia-compliant financial decisions, improve budgeting discipline, and use financing instruments (Azman et al., 2023; Srisusilawati et al., 2022). Intellectual capital is also relevant because knowledge, routines, and relational resources can strengthen efficiency, innovation, and adaptability (Castro et al., 2021; Beltramino et al., 2022; Arshad et al., 2023). In addition, working capital management supports day-to-day operations by maintaining liquidity through the management of cash, receivables, inventories, and short-term obligations (Barros et al., 2022; Vukovic et al., 2023; Hong et al., 2023).

However, prior evidence remains inconclusive and still leaves room for academic debate. Studies generally report positive relationships between Islamic financial literacy and business performance or sustainability, yet the strength and consistency of those relationships vary across contexts (Nugraha et al., 2022; Siddik et al., 2023; Lontchi et al., 2023). Similar variation appears in the intellectual capital and working capital literature, where findings depend on context, measurement, and firm characteristics (Beltramino et al., 2022; AlQershi et al., 2023; Banerjee & Deb, 2023; Suntraruk, 2023). Moreover, most earlier studies examined these determinants separately or focused on conventional SME and corporate settings. Consequently, prior research still offers limited explanation of how these factors jointly sustain microenterprises in an Islamic microfinance environment.

Another unresolved issue concerns the mechanism linking those determinants to sustainability. In microenterprises, knowledge and internal resources do not automatically

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translate into continuity unless they first improve financial outcomes. Financial performance is therefore likely to serve as an important mechanism because better literacy, stronger intangible resources, and more disciplined working capital management should improve profitability, cash flow adequacy, and financial stability, which in turn support sustainability (Menne et al., 2023; Jeandry & Fajriyanti, 2023; Tulcanaza-Prieto et al., 2022). This mechanism is especially relevant in an empowerment-based Islamic microfinance setting, where continuity depends not only on access to capital but also on the entrepreneur's ability to transform knowledge and resources into financial resilience.

Based on these arguments, the present study identifies three main gaps in the literature. First, previous studies provide mixed evidence on the effects of Islamic financial literacy, intellectual capital, and working capital on financial performance and business continuity. Second, limited research examines these determinants simultaneously within a single framework. Third, the mediating role of financial performance remains underexplored in non-profit Islamic microfinance settings. Accordingly, this study differs from prior research by jointly examining those three determinants in Baznas Microfinance Desa and by testing financial performance as the mechanism through which they sustain microenterprises. Therefore, this study aims to examine the effects of Islamic financial literacy, intellectual capital, and working capital on financial performance and microenterprise sustainability among Baznas Microfinance Desa partners in East Java, Indonesia.

METHODS

This study employed a quantitative explanatory design to examine the relationships among Islamic financial literacy, intellectual capital, working capital, financial performance, and microenterprise sustainability. The research was conducted among partners of Baznas Microfinance Desa in East Java, Indonesia, covering three operational areas: Malang City, Ponorogo Regency, and Sampang Regency. The unit of analysis was the owner or manager of a microenterprise registered as a Baznas Microfinance Desa partner.

Respondents were selected through a multistage sampling procedure. First, the study areas were grouped according to the operational coverage of Baznas Microfinance Desa. Second, the sample was proportionally allocated across the three regions to reflect the distribution of partners in each area and to improve representativeness (Creswell & Creswell, 2018). Third, respondents within each area were recruited through convenience sampling based on their availability during the survey period. To be included in the study, respondents had to meet four criteria: they had to be active partners of Baznas Microfinance Desa, operate a microenterprise, be directly involved in business management, and be willing to complete the questionnaire. Based on a 95% confidence level and a 5% margin of error, the required sample size was 285 respondents, all of whom met the eligibility criteria.

Data were collected through a structured questionnaire using a five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree. This approach was considered

appropriate because many microenterprises did not maintain standardized financial records; therefore, perceptual measures provide a practical means of capturing business conditions and financial outcomes in this context (Tulcanaza-Prieto et al., 2022).

The research framework positions Islamic financial literacy, intellectual capital, and working capital as exogenous variables, financial performance as a mediating variable, and microenterprise sustainability as the endogenous variable. Within this framework, Islamic financial literacy, intellectual capital, and working capital are expected to influence microenterprise sustainability both directly and indirectly through financial performance. In other words, financial performance is the mechanism through which financial capability and internal resources translate into sustainable business outcomes. The operational definitions of the variables are presented in Table 1.

Table 1. Operational Definitions of Variables

Variable	Operational Definition	Main Dimensions/Indicators	Key References
Islamic Financial Literacy	Knowledge, understanding, and financial behavior in managing business finances in accordance with Islamic principles	Islamic Financial Behavior; Islamic financial knowledge; Islamic financial attitude; Islamic financial awareness	Dinc et al. (2021), Osman et al. (2024), and Yusfiarto et al. (2022)
Intellectual Capital	Intangible resources embedded in the business that support value creation and continuity	Human capital; relational capital; spiritual capital; trust capital	Ferreira et al. (2022), Castro et al. (2021), and AlQershi et al. (2023)
Working Capital	Management of short-term resources required for daily operations	Inventory management; receivables management; cash management; payable management	Barros et al., 2022), Hong et al. (2023), Vukovic et al. (2023)
Financial Performance	Perceived financial condition of the business	Productivity; sales growth; profitability; cost efficiency	Lontchi et al. (2023), Nurjannah et al. (2023), Tulcanaza-Prieto et al. (2022)
Microenterprise Sustainability	Ability to maintain continuity and preserve business quality over time	Financial performance; flexibility; quality	Gorondutse et al. (2020), Raharjo et al., (2023), Kurniasari et al. (2023).

Data analysis was carried out using Partial Least Squares Structural Equation Modeling (PLS-SEM). This method was chosen because the model involved multiple latent constructs and mediation effects, making PLS-SEM appropriate for predictive analysis in applied business research (Hair et al., 2022). Furthermore, the procedure used consisted of two stages. The first stage assessed the measurement model through indicator reliability, internal consistency reliability, convergent validity, and discriminant validity. Outer loadings above 0.70, Cronbach's alpha and composite reliability above 0.70, and average variance extracted (AVE) above 0.50 were used as the main criteria. The second stage evaluated the structural model using path coefficients, coefficients of determination (R^2), and indirect effects to test the mediating role of financial performance. Statistical

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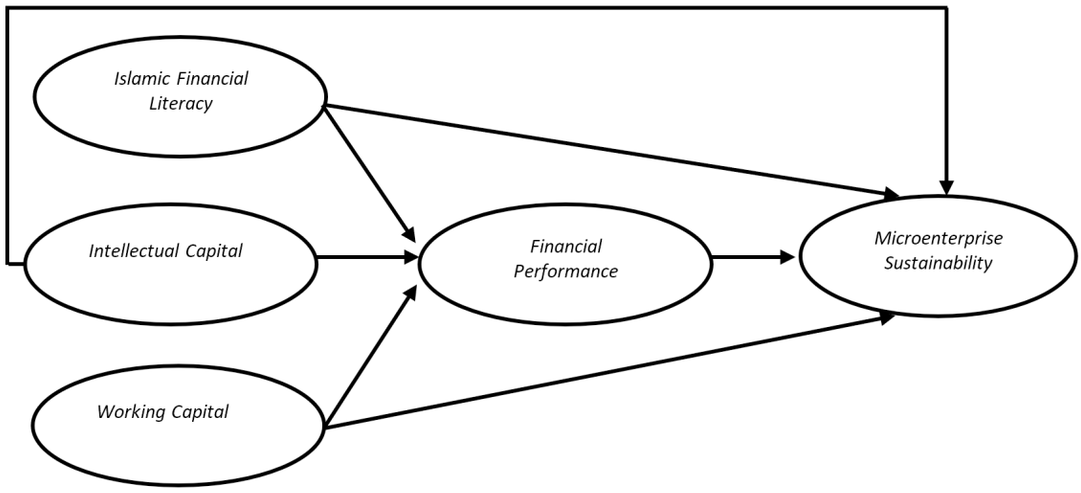
significance was assessed through bootstrapping. Based on these ideas, a research model was developed and is shown in Figure 1.

Figure 1. The Research Model



RESULTS AND DISCUSSION

The main findings of this study are presented in Table 5. All proposed direct and indirect relationships are positive and statistically significant. Islamic financial literacy, intellectual capital, and working capital improve financial performance and microenterprise sustainability. Among these antecedents, working capital appears as the strongest operational driver, while financial performance exerts the most immediate influence on sustainability and mediates the effects of the three antecedent variables. These findings indicate that microenterprise sustainability in Baznas Microfinance Desa depends not only on access to resources, but also on the entrepreneur's ability to transform financial knowledge, internal capability, and liquidity management into stronger financial outcomes.

Table 2 presents the profile of the respondents. Female microentrepreneurs dominate the sample, and most respondents are in the productive age group. This profile indicates that the study captures active business actors who are directly involved in managing their enterprises within the Baznas Microfinance Desa program. Such characteristics are relevant because business continuity in this segment is closely associated with practical experience, financial discipline, and the ability to manage limited resources daily.

The measurement model met the required standards of reliability and convergent validity. As shown in Table 3, all indicator loadings were above 0.70, Cronbach's alpha and composite reliability values exceeded 0.70, and all AVE values were above 0.50. These results confirm that the indicators consistently measured their respective constructs and that the model was appropriate for further structural analysis (Hair et al., 2022). Discriminant validity was also achieved. Table 3 shows that the square root of the AVE for each construct was greater than its correlations with other constructs, indicating that each construct was empirically distinct from the others.

Table 2. Profile of the sample

Characteristics	Frequency (n)	Percentage (%)
Gender		
Male	56	19.7
Female	229	80.4
Age		
<20 years	1	0.4
21 - 30 years	25	8.8
31 - 40 years	85	29.8
41 - 50 years	107	37.5
> 50 years	67	23.5
Education		
Elementary School / Equivalent	29	10.2
Junior High School / Equivalent	162	56.8
High School / Equivalent	61	21.4
Diploma	12	4.2
Bachelor	20	7.0
Master	1	0.4
Business Sector		
Agribusiness	9	3.2
Fashion	13	4.6
Services	13	4.6
Creative	4	1.4
Culinary	194	68.1
Retail/Grocery	38	13.3
Other	14	4.9
Business Duration		
1 - 5 years	128	44.9
6 - 10 years	108	37.9
11 - 15 years	28	9.8
16 - 20 years	10	3.5
> 20 years	11	3.9
Income		
< IDR 50.000.000	156	54.7
IDR 50.000.001 - IDR 100.000.000	62	21.8
IDR 100.000.001 - IDR 200.000.000	47	16.5
IDR 200.000.001 - IDR 300.000.000	16	5.6
> IDR 300.000.001	4	1.4
Profit		
< IDR 10.000.000	131	46.0
IDR 10.000.001 - IDR 50.000.000	118	41.4
IDR 50.000.001 - IDR 100.000.000	29	10.2
IDR 100.000.001 - IDR 300.000.000	5	1.8
> IDR 300.000.001	2	0.7

Source: Authors' calculations (2025)

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Discriminant validity was also achieved. The Fornell and Larcker criterion in Table 4 shows that the square root of the AVE for each construct was greater than its correlations with other constructs, indicating that each construct was empirically distinct from the others (Fornell & Larcker, 1981).

Table 3. Measurement model evaluation

Variable	Indicator	Loading Factor	Cronbach's Alpha	Composite Reliability	AVE
Islamic Financial Literacy	IFL1	0.851	0.883	0.919	0.740
	IFL2	0.849			
	IFL3	0.856			
	IFL4	0.886			
Intellectual Capital	IC1	0.828	0.856	0.902	0.698
	IC2	0.907			
	IC3	0.794			
	IC4	0.810			
Working Capital	WC1	0.829	0.822	0.882	0.652
	WC2	0.855			
	WC3	0.785			
	WC4	0.758			
Financial Performance	FP1	0.874	0.905	0.933	0.778
	FP2	0.906			
	FP3	0.885			
	FP4	0.863			
Business Sustainability	BS1	0.873	0.872	0.921	0.796
	BS2	0.924			
	BS3	0.878			

Source: Authors' calculations (2025).

Islamic financial literacy positively affects financial performance and microenterprise sustainability. This finding suggests that microentrepreneurs who understand Sharia-compliant financial principles are better able to plan expenditures, allocate funds, and choose financing practices that fit their business needs. In turn, this capability supports stronger financial outcomes and more stable business continuity. This result is consistent with earlier studies showing that Islamic financial literacy strengthens financial behavior, improves business performance, and supports sustainability among small enterprises (Azman et al., 2023; Srisusilawati et al., 2022; Siddik et al., 2023; Habriyanto et al., 2022). At the same time, this study extends the literature by showing that the same relationship also holds in Baznas Microfinance Desa, where enterprise development is embedded in an empowerment-based Islamic microfinance setting rather than a conventional profit-oriented one.

Table 4. Discriminant Validity According to Fornell and Larcker

	IFL	IC	WC	FP	BS
IFL	0.892				
IC	0.701	0.882			
WC	0.706	0.631	0.836		
FP	0.642	0.600	0.653	0.860	
BS	0.690	0.613	0.668	0.561	0.808

Source: Authors' calculations, 2025.

Table 5. The Results of the Hypothesis Test

Hypotheses	Original Sample	Standard Deviation	T Statistics	P Values	Decision
H1: IFL -> FP	0.266	0.077	3.477	0.001	Accepted
H2: IC -> FP	0.267	0.091	2.945	0.003	Accepted
H3: WC -> FP	0.285	0.075	3.776	0.000	Accepted
H4: IFL -> BS	0.164	0.068	2.417	0.016	Accepted
H5: IC -> BS	0.244	0.075	3.259	0.001	Accepted
H6: WC -> BS	0.256	0.072	3.580	0.000	Accepted
H7: FP -> BS	0.292	0.062	4.721	0.000	Accepted
H8: IFL -> FP -> BS	0.078	0.027	2.915	0.004	Accepted
H9: IC -> FP -> BS	0.078	0.031	2.543	0.011	Accepted
H10: WC -> FP -> BS	0.083	0.033	2.531	0.012	Accepted

Source: Authors' calculations (2025)

Intellectual capital also positively affects financial performance and microenterprise sustainability. This result implies that knowledge, routines, and relational resources help microenterprises improve efficiency, preserve customer trust, and adapt to changing conditions despite limited tangible assets. In this context, intellectual capital functions as a strategic internal resource rather than merely a supporting factor. This finding supports prior studies that identify intellectual capital as an important source of value creation, business performance, and long-term resilience (Castro et al., 2021; Beltramino et al., 2022; Arshad et al., 2023; AlQershi et al., 2023). Compared with those earlier studies, the present research shows that intellectual capital also matters in small empowerment-based businesses with simpler organizational structures and weaker formal systems.

Working capital is another significant determinant of financial performance and microenterprise sustainability, and it appears as the strongest operational driver in the model. This pattern is especially important because it shows that liquidity discipline is the most immediate lever for sustaining microenterprise operations. In practice, microenterprises are highly sensitive to cash shortages, delayed receivables, unstable inventory turnover, and short-term payment obligations. For this reason, working capital management directly affects whether a business can continue operating from one cycle to the next. This finding is in line with previous studies showing that working-capital discipline improves efficiency,

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profitability, and sustainable growth (Barros et al., 2022; Hong et al., 2023; Vukovic et al., 2023; Banerjee & Deb, 2023; Suntraruk, 2023). Within this study, the stronger role of working capital indicates that operational liquidity is the most immediate challenge faced by microenterprises supported by Islamic microfinance programs.

Financial performance positively affects microenterprise sustainability and also mediates the effects of Islamic financial literacy, intellectual capital, and working capital on sustainability. This result clarifies the mechanism linking entrepreneurial capability and internal resources to business continuity. In other words, literacy, intangible capability, and liquidity management do not strengthen sustainability automatically; they do so by first improving profitability, cash-flow adequacy, and financial stability. This mediating role is particularly important because it shows that sustainability is not only a direct consequence of knowledge and resources, but also the result of how those factors are translated into financial outcomes. This finding is consistent with previous studies that position financial performance as a pathway linking firm capability and sustainability outcomes (Menne et al., 2023; Jeandry & Fajriyanti, 2023; Bastomi & Sudaryanti, 2024; Gao et al., 2023). The contribution of this study lies in showing that the same mechanism also operates in Baznas Microfinance Desa, which differs from conventional financing institutions because it is rooted in Islamic social finance and empowerment.

Overall, these findings position the study more clearly within the existing literature. Many earlier studies examined Islamic financial literacy, intellectual capital, or working capital separately, and most were conducted in conventional SME or corporate contexts. By contrast, this study demonstrates that the three determinants jointly explain microenterprise sustainability through financial performance in an Islamic microfinance environment. This integrated explanation is the study's main contribution. It also carries practical implications because it shows that empowerment programs should not focus on capital provision alone. Baznas Microfinance Desa and similar institutions need to strengthen Islamic financial literacy support, capability-oriented mentoring, and simple working-capital management practices that are feasible for microentrepreneurs. Such an approach is more likely to improve financial performance and, in turn, sustain microenterprises over time.

CONCLUSION

This study demonstrates that Islamic financial literacy, intellectual capital, and working capital are significant determinants of microenterprise sustainability among partners of Baznas Microfinance Desa in East Java, Indonesia. These factors influence sustainability both directly and indirectly through financial performance. In this model, financial performance acts as the key mechanism through which Sharia-compliant financial knowledge, internal capability, and working-capital discipline are translated into business continuity. Accordingly, this study answers the research objective by showing that the combined role of financial capability, intangible resources, operational liquidity, and financial outcomes shapes microenterprise sustainability in an Islamic microfinance setting.

From a practical and policy perspective, the findings imply that Islamic microfinance programs should move beyond capital provision alone. Baznas Microfinance Desa and

similar institutions need to strengthen applied Islamic financial literacy, provide capability-oriented mentoring, and improve simple working-capital supervision for microentrepreneurs. These interventions are important for improving liquidity management, strengthening financial performance, and sustaining business continuity. Policy support is also needed through training, business assistance, and financial monitoring schemes tailored to microenterprise conditions. This study is limited by its cross-sectional design and the use of perception-based measures, particularly for financial performance. Future research may use longitudinal data, incorporate more objective financial indicators, and compare different Islamic microfinance settings to examine the broader applicability of the model.

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Countries	2010	2020
ASEAN Countries		
Indonesia	5,814 (71)	5,54 (71)
Malaysia	6,608 (36)	6,62 (36)
Thailand	6,436 (42)	5,96 (50)
Filipina	6,403(44)	5,71 (63)
Singapura	7,719 (11)	8,00 (6)
Vietnam	6,080 (61)	5,64 (68)

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