

The Impact of Artificial Intelligence Technology Penetration on Corporate Resilience: Empirical Evidence from Indonesian Listed Companies

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ABSTRACT: This study examines the impact of artificial intelligence (AI) technology penetration on corporate resilience and its underlying mechanisms, using a sample of companies listed on the Indonesia Stock Exchange from 2015 to 2024. The findings indicate that AI technology penetration significantly enhances corporate resilience, a conclusion that remains robust after a series of tests including variable substitution, high-dimensional fixed effects control, and endogeneity treatment. Heterogeneity analysis reveals that the resilience-enabling effect of AI is more dominant in large enterprises, firms with higher levels of digitization, and manufacturing sectors, whereas it is not significant in small and medium-sized enterprises, firms with lower digitization levels, or non-manufacturing industries. Further mechanism testing shows that regional broadband infrastructure plays a partial mediating role in the relationship between AI penetration and corporate resilience. This study provides empirical evidence for enhancing resilience through digital transformation in emerging markets and offers insights for corporate decision-making, policy guidance, and investment evaluation.

KEYWORDS: AI technology penetration; Corporate resilience; Indonesian listed companies

I. INTRODUCTION

In an era defined by volatility, uncertainty, complexity, and ambiguity (VUCA)—marked by climate upheaval, recurrent geopolitical conflicts, and profound reconfiguration of global supply chains—organizational resilience has evolved from a strategic advantage into a basic prerequisite for survival. Resilience here means a firm's ability to foresee disruptions, prepare for them, respond effectively, recover quickly, and even grow stronger in the face of adversity (Gao et al., 2021). This need is especially pressing for companies in emerging markets, where unstable institutions, weak infrastructure, and frequent external shocks make building resilience both more difficult and more urgent (Wang et al., 2022). At the same time, artificial intelligence (AI) is increasingly embedded in core business functions. AI is now used to improve supply chains, predict risks in real time, support fast-changing decisions, and strengthen customer relationships—making it a key tool for managing crises and adapting to change (Dwivedi et al., 2023). Yet, the actual effectiveness and underlying mechanisms of AI-driven resilience remain underexplored—particularly in institutionally distinct emerging markets. This gap is especially pronounced in Indonesia, the largest economy in Southeast Asia, where the promise of AI must be rigorously tested against the realities of its unique institutional and operational context.

As the world's fourth-most populous nation and Southeast Asia's digital economy leader, Indonesia's listed enterprises stand at the forefront of national economic transformation. Yet they simultaneously grapple with profound resilience challenges: geographical fragmentation across its vast archipelago, persistent infrastructure gaps, an evolving policy landscape, and severe pandemic disruptions (Hikam et al., 2024). While the government actively promotes its Making Indonesia 4.0 strategy to accelerate penetration of frontier technologies like AI, a stubborn gap persists between corporate awareness of these tools and their practical implementation (Aryanto et al., 2023). Crucially, it remains unclear whether technology investments genuinely enhance firms' capacity to withstand shocks. More fundamentally, under conditions of resource constraints and institutional complexity, do pathways for building resilience through AI converge with those observed in advanced economies?

Existing research primarily examines established Western economies or stays largely theoretical (Santosa et al., 2024). There is a serious lack of empirical evidence from firms in emerging markets—and even less attention to Indonesia, a paradigmatic "high-volatility, high-growth" economy with its own distinct institutional logic. This knowledge gap not only limits how resilience theory can develop across diverse contexts, but also hinders Indonesian and other Global firms from designing effective digital resilience strategies.

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Building on these gaps, this study focuses on firms listed on the Indonesia Stock Exchange (IDX) to investigate the causal impact of AI penetration on firm resilience—and the boundary conditions under which it operates. Specifically, it addresses two core questions: (1) In Indonesia's distinctive "high-volatility, high-growth" context, does AI penetration genuinely enhance firms' ability to withstand, adapt to, and recover from shocks—or does it initially yield neutral or even negative effects, given the high costs of implementation and the disruption of the organization? (2) Does this effect differ systematically across firms depending on their industry, ownership structure, or exposure to institutional constraints?

To answer these questions, the study constructs a firm-level measure of AI penetration and uses sales revenue growth as a proxy for resilience during systemic shocks. Using panel data and controlling for firm characteristics and macroeconomic factors, we conduct rigorous empirical tests. The findings are expected to offer key micro-level evidence for the emerging "technology–resilience" framework in emerging markets and provide practical guidance for managers and policymakers in Indonesia and similar economies on prioritizing digital transformation and allocating resources efficiently.

II. LITERATURE REVIEW

A. The Impact of Artificial Intelligence Technology Penetration on Corporate Resilience

Artificial intelligence (AI) penetration refers to the deep integration and application of AI—as a general-purpose technology—across multiple dimensions of a firm, including production, operations, management, and decision-making (Haleem et al., 2022). It encompasses not only the penetration of tangible AI tools such as robotics and intelligent algorithms, but more fundamentally represents a transformation of core business processes and capability foundations through data-driven insights and intelligent automation.

Existing research suggests that AI penetration may significantly enhance firm resilience through several key mechanisms. First, AI improves operational efficiency and adaptability. By optimizing production processes and boosting labor productivity, AI enables firms to adjust capacity more flexibly in response to demand fluctuations or supply chain disruptions (Bandhana et al., 2025). For instance, the deployment of industrial robots directly strengthens manufacturing firms' agility and responsiveness. Second, AI enhances risk prediction and response capabilities. Through advanced data analytic, machine learning, and predictive modeling, firms can identify emerging risks earlier and more accurately, simulate the outcomes of alternative strategies, and thereby make faster, better-informed decisions (Fan, 2025). Third, AI supports more efficient resource allocation and fosters innovation. By enabling more precise investment and operational decisions, AI helps alleviate financing constraints and sustains critical activities during crises. Moreover, it catalyzes technological innovation, opening new competitive advantages and growth trajectories—key sources of long-term resilience (Li, 2023). Building on these theoretical and empirical insights, we propose the following hypothesis:

H1: *AI penetration has a significant positive effect on firm resilience.*

B. The Mediating Role of Broadband

In this study, broadband refers specifically to the regional level of digital infrastructure in the location where a firm operates. It is commonly measured by indicators such as fiber-optic network coverage or fixed broadband subscriptions per 100 inhabitants, and represents the foundational physical and data-transmission capacity that underpins a modern digital economy (Endres et al., 2024). As a frontier technological innovation, AI cannot realize its full value-creation potential in isolation. Its effectiveness critically depends on complementary assets and enabling environmental conditions (Avezov, 2025). Among these, high-speed, stable, and low-latency broadband connectivity serves as a key complementary asset. It functions as the essential "digital foundation" that enables data-intensive AI applications to be deployed, scaled, and operated effectively (He et al., 2024). Without this underlying infrastructure, the transmission, processing, and real-time utilization of the vast data flows required by AI systems would be severely constrained—limiting both their functionality and economic impact.

The mediating role of broadband infrastructure can be explain through two sequential stages. First, the deeper penetration of AI places heightened demands on network performance—such as high bandwidth, low latency, and reliability. This not only encourage firms to locate in areas with superior broadband infrastructure but also, through agglomeration effects, stimulates local investment in further network upgrades. As a result, a strong endogenous link emerges between AI penetration and the availability of high-quality broadband (Briglaue et al., 2024). Second, once in place, robust broadband infrastructure amplifies the effectiveness of AI applications by ensuring the operational continuity of intelligent systems, enhancing real-time responsiveness and cross-unit coordination, and facilitating the inflow of external knowledge and technological spillovers. These mechanisms collectively strengthen a firm's ability to anticipate, absorb, and adapt to shocks—thereby translating AI penetration into tangible gains in resilience (Li et al., 2024). Building on this reasoning, we propose the following hypothesis:

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H2: *Broadband infrastructure plays a significant partial mediating role in the relationship between AI penetration and firm resilience.*

III. DATA SOURCES AND VARIABLE MEASUREMENTS

A. Econometric Model

$$Resis_{it} = \alpha_0 + \alpha_1 AI_{it} + \alpha_2 Control_{it} + \delta_i + \mu_t + \epsilon_{it} \quad (1)$$

In equation (1), i denotes the firm, t denotes year. The dependent variable, *Resis* represents firm resilience, measured as the ratio of current-year to prior-year sales revenue. The main explanatory variable, *AI* captures the degree of AI technology penetration, proxied by the ratio of R&D expenditure to operating revenue. The model also includes a vector of control variables (*Control*), δ captures firm fixed effects to account for time-invariant firm-specific characteristics, μ captures year fixed effects to absorb common macroeconomic shocks, and ϵ is the random error term.

B. Data Description

This study focuses on firms listed on the Indonesia Stock Exchange (IDX) over the sample period from 2015 to 2024. To ensure the robustness and reliability of the empirical results, we applied a standardized data screening and cleaning procedure to construct the final analytical sample.

First, we excluded firms that were effectively non-operational during the sample period, such cases generally reflect abnormal operating conditions that may affect the estimated results. Second, we removed observations with missing values for key variables, particularly those with consecutive or systemic gaps in critical data. Finally, to mitigate the influence of outliers, we winsorized all continuous variables at the 1st and 99th percentiles. These steps collectively help enhance data quality and reduce potential estimation bias, thereby strengthening the validity of our empirical analysis.

C. Variable Definition

a. Dependent Variable

Firm resilience refers to the comprehensive dynamic capability of a firm to withstand external shocks, recover from disruptions, and reorient its operations through adaptive adjustment or even transformation (Ortiz-de-Mandojana et al., 2015; Sukardi et al., 2024). In empirical practice, sales revenue growth rate is widely used as a key indicator of this capacity, as it directly captures a firm's ability—amid market volatility, competitive pressures, or systemic shocks—to sustain its business scale, regain market position, and even achieve growth (Hongliang et al., 2024). A higher sales growth rate suggests that a firm can effectively withstand in the adverse conditions, swiftly adjust strategy, seize opportunities, and drive business recovery and expansion, thereby demonstrating strong resilience. Conversely, persistently low or negative growth typically signals limited adaptive capacity and operational fragility in the face of external challenges.

In the Indonesian context, Rahman et al. (2023) find that sales growth is a statistically significant determinant of firm resilience, offering direct empirical justification for using sales revenue growth as a proxy for resilience. Similarly, in the manufacturing sector, Eksandy et al. (2022) observe that observed that sharp fluctuations in annual sales revenue of Indonesian manufacturing companies directly reflect differences in their ability to withstand market shocks, further validating this indicator as a measure of corporate resilience. Building on this literature, and to systematically assess firm resilience, this study follows Hu et al. (2024) by using sales growth rate as the primary dependent variable, calculated as:

$$Sales\ Growth = \frac{Current\ year\ Sales - Previous\ year\ Sales}{Previous\ year\ Sales} \quad (2)$$

This measure effectively captures the short-term impact of external demand shocks and reflects a firm's ability to maintain market performance in turbulent conditions. To further reveal firms' financial buffering capacity—a critical dimension of resilience—we additionally adopt a second resilience proxy for robustness test, following Sambowo et al. (2021): we adopts the ratio of reserve funds to redundant resources used as a proxy indicator for resilience.

b. Independent Variable

Artificial intelligence (AI) technology penetration denotes the extent and intensity of AI penetration and integration by firms across key functional areas—including production, operations, management, and decision-making—serving as a holistic indicator of their maturity in applying AI technologies (Chen et al., 2023). In practice, the ratio of R&D expenditure to operating revenue is widely used as a key proxy for this construct. This metric directly reflects the intensity of a firm's resource commitment to AI-related innovation. A higher R&D-to-revenue ratio suggests that the firm is allocating a larger share of its resources to

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technological advancement—including AI—indicating deeper integration of AI into its operational workflows and strategic priorities, and signaling a more central role of AI in driving competitive capability (Lee et al., 2022).

In the Indonesian context, empirical evidence further supports the link between AI penetration and enhanced firm resilience. In the manufacturing sector, Suraji et al. (2025) find that AI penetration significantly improves operational efficiency, transforms business models, enhances decision-making, and reshapes employee roles. Similarly, in the financial services industry, Ghani et al. (2022) identify AI as a critical enabler of better organizational decision-making, faster task execution, and higher worker productivity—all of which strengthen a firm's capacity to adapt to and recover from external shocks. Building on this body of research, and to systematically assess the level of AI technology penetration among Indonesian firms, this study follows the approach of Wu et al. (2025) by using the ratio of R&D expenditure to operating revenue as the core explanatory variable. This measure effectively captures the intensity of a firm's financial commitment to exploring and applying frontier technologies, including AI. To reveals the development path of achieving intelligent upgrades through technology introduction, integration, and application—we additionally draw on Xiangling et al. (2024) and employ ICT investment as a supplementary proxy for digital investment in our analysis.

c. Control Variables

Following Zhong et al. (2024), this study includes the following control variables to account for key firm-level characteristics; Size: the natural logarithm of total assets, Leverage (Lev): total liabilities divided by total assets, Cash: cash equivalents scaled by total assets, Fixed Assets (Fix): net fixed assets as a share of total assets, Total Turnover Asset (TTA): total revenue divided by total assets, Growth: the annual growth rate of total assets, ROA: net profit divided by total assets.

Table 1 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Resis	2465	0.075	0.286	-0.867	0.960
AI	2465	21.59	0.465	20.70	22.45
Size	2465	28.97	1.760	24.60	33.62
Lev	2465	0.553	0.447	0.014	4.371
Cash	2465	0.094	0.103	0.001	0.569
Fix	2465	0.479	0.288	0.004	0.995
TTA	2465	0.356	0.258	0.006	0.972
Growth	2465	-0.038	0.337	-0.935	0.953
Roa	2465	0.024	0.995	-0.575	0.369

IV. RESULT AND ANALAYSIS

A. Benchmark Regression

The baseline regression results are presented in Table 2. To examine the impact of AI technology penetration on firm resilience, we estimate a series of progressively specified regression models.

Table 2. Baseline Regression Result

Variables	Resis (1)	Resis (2)	Resis (3)
AI	0.044*** (0.012)	0.158*** (0.053)	0.167*** (0.053)
Size			-0.021 (0.016)
Lev			0.101** (0.043)
Cash			0.001 (0.086)
Fix			-0.048 (0.030)
TTA			-0.023 (0.024)
Growth			0.045*** (0.015)

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Roa			0.661*** (0.080)
Constant	-0.874*** (0.251)	-3.327*** (1.155)	-2.959** (1.225)
Firm & Year	No	Yes	Yes
Observations	2,465	2,465	2,465
R-squared	0.005	0.385	0.409

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Column (1) reports a basic model without control variables or fixed effects; the coefficient on AI penetration is positive and statistically significant at the 1% level. In Column (2), we add year fixed effects, and the AI coefficient remains positive and highly significant. Column (3) presents the full specification, incorporating firm and year fixed effects along with the full set of control variables. Here, the coefficient on AI penetration is 0.167 and continues to be significant at the 1% level. This consistent and robust positive association across model specifications indicates that greater AI penetration is significantly associated with higher firm resilience. The findings strongly support Hypothesis 1, confirming that AI penetration enhances firms' capacity to withstand, adapt to, and recover from external shocks—even after rigorously accounting for unobserved heterogeneity and firm-specific characteristics.

B. Robustness Test

a. Replace The Dependent Variable

The baseline analysis uses sales revenue growth as the primary measure of firm resilience, which primarily captures a firm's adaptive and recovery capacity on the market front. However, this indicator may be partially influenced by external factors such as pricing strategies, promotional activities, or non-recurring income, potentially reflecting changes in scale more than underlying operational or financial quality (Safón et al., 2023). To more directly assess a firm's internal financial buffer and risk-absorbing capacity, we using the ratio of reserve funds to redundant resources to replace dependent variable in this robustness test, following Sambowo et al. (2021). This metric reflects the extent to which firms hold excess resources in highly liquid, low-risk forms—such as cash and cash equivalents—thereby gauging their immediate financial capacity to respond to unexpected shocks (Han & Feng, 2025). Unlike sales growth, which emphasizes market performance, this reserve-based indicator focuses on the robustness of internal financial structure and the strategic stockpiling of financial flexibility. It directly captures the thickness of a firm's financial "safety cushion" and its intrinsic ability to absorb adverse events without operational disruption.

As shown in Column (1) of Table 3, the coefficient on AI penetration remains positive and statistically significant at the 1% level, closely aligning with the baseline findings. This consistency reinforces the core conclusion that AI penetration not only enhances market-facing resilience but also strengthens firms' internal financial preparedness—providing robust evidence for Hypothesis 1 across alternative dimensions of resilience.

b. Replace The Independent Variable

The baseline specification we measures AI technology penetration by using the ratio of R&D expenditure to operating revenue, which primarily captures a firm's internal resource commitment to technological innovation and knowledge exploration. However, this metric may overlook an equally important path in smart transformation: the penetration and integration of AI or digital solutions purchased from external parties through a procurement and implementation process—rather than internal development (Mustafa et al., 2025). Relying solely on R&D intensity could thus introduce a measurement bias that underrepresents firms advancing digitalization through technology acquisition. To more comprehensively capture firms' practical efforts in achieving intelligent upgrading through technology penetration, integration, and deployment, we adopt ICT (Information and Communication Technology) investment to replace the dependent variable for robustness test, following Xiangling et al. (2024). This measure is typically constructed as the share of capital expenditures—reported in the cash flow statement—related to software, hardware, information systems, and digital services, scaled by either operating revenue or total assets. It directly reflects the extent to which firms are investing in the capitalization and operational integration of mature external digital technologies (Chen, 2025).

As reported in Column (2) of Table 3, the coefficient on this digital investment variable (Digital) showing a positive and statistically significant at the 1% level, consistent with the baseline results. This robustness check confirms that the positive link between AI-related digitalization and firm resilience holds not only for internally developed innovation but also for externally driven technological penetration—thereby strengthening the validity and generalizability of our findings.

c. Adding High-Dimensional Effects

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to prevent from potential omitted variable bias arising from unobserved industry-level commonalities, firm-specific heterogeneity, and macroeconomic time trends, this study further conducts a robustness check using a high-dimensional fixed effects model. Specifically, we simultaneously include industry, firm, and year fixed effects in the regression specification and cluster standard errors at the firm level to address potential cross-sectional dependence and serial correlation in the error structure.

As shown in Column (3) of Table 3, the coefficient on AI technology penetration remains positive and statistically significant at the 1% level even after incorporating these high-dimensional controls. This result closely aligns with the baseline findings, confirming that the positive association between AI penetration and firm resilience is robust to the inclusion of comprehensive fixed effects and rigorous error clustering—thereby enhancing the credibility of our core conclusion.

Table 3. Roboustness Test Result

Variables	Resis_2 (1)	Resis (2)	Resis (3)
AI	0.201*** (0.066)		0.167*** (0.044)
Digital		0.069*** (0.026)	
Constant	-3.161** (1.546)	-1.879 (1.066)	-2.959*** (1.036)
Controls Var	Yes	Yes	Yes
Firm & Year	Yes	Yes	Yes
Firm Cluster	No	No	Yes
Observations	2,465	2,465	2,465
R-squared	0.539	0.408	0.409

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

C. Endogeneity Test

The relationship between AI technology penetration (AI) and firm resilience may be subject to endogeneity concerns, particularly reverse causality—whereby more resilient firms may be better positioned to invest in AI—or omitted variable bias. To address this, we adopt a Bartik-style instrumental variable (IV) approach following Bartik (1991). Specifically, we construct an instrument using the average AI penetration of other firms in the same industry and year, excluding the focal firm itself. This instrument is valid for two reasons. First, firms within the same industry are commonly exposed to similar technological trends, competitive pressures, and supply chain dynamics, which tend to induce correlated patterns in AI penetration. As a result, the industry-year average AI level is strongly correlated with a given firm's own AI penetration—a condition known as relevance (Rejeb et al., 2025). On the other hand, the average AI penetration rate at the industry level primarily influences corporate resilience by affecting companies' own decisions to adopt AI technologies. It does not mechanically determine operational outcomes or shock responses at the firm level, thereby largely satisfying the exclusion restriction (Yin et al., 2025).

Table 4. Endogeneity Test Result

Variables	First Stage AI_adoption (1)	Second Stage Resis (2)
IV	0.881*** (0.095)	
AI		0.659** (0.272)
Cragg-Donald Anderson Statistic		86.343 95.641***
Controls Var	Yes	Yes
Firm & Year	Yes	Yes
Observations	2,465	2,465
R-squared		0.015

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

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Table 4 columns (1) and (2) present the two-stage least squares (2SLS) regression results. In the first stage, regression reveals that the coefficient for the instrumental variable is significantly positive, indicating a strong correlation with AI penetration. In the second stage, the coefficient for AI remains statistically significant and positive, further supporting the positive impact of AI technology penetration on corporate resilience. Diagnostic tests further support the validity of the instrument. The Cragg–Donald Wald F statistic is 86.343, far exceeding the Stock–Yogo critical value of 16.38 at the 10% significance level for the weak-identification threshold, allowing us to confidently reject the null hypothesis of a weak instrument. Additionally, the Anderson canonical correlation LM statistic is 95.641 and significant at the 1% level, strongly rejecting the null hypothesis of under-identification. This shows that the penetration of AI technology is not merely a phenomenon accompanying the emergence of highly resilient companies, but rather functions as a causal driver that meaningfully strengthens a firm’s capacity to withstand, adapt to, and recover from external shocks. This substantially strengthens the causal credibility of our findings and provides robust empirical support our main analysis.

D. Heterogeneity Test

To further examine whether the impact of AI penetration on company resilience differs across firms with varying enterprise size, digitalization level, or industry characteristic, we conduct a series of heterogeneity analyses. Specifically, we perform subsample regressions along four key dimensions

a. Firm Size

Following Andreas et al. (2022), we divided the sample into large enterprises and small to medium-sized enterprises based on the median of Total Assets. Columns (1) and (2) of Table 5 present the results. For large firms, the coefficient on AI penetration is positive and statistically significant, indicating a clear resilience-enhancing effect of AI. In contrast, for SMEs, the AI coefficient is positive but statistically insignificant, suggesting that the resilience benefits of AI penetration have not yet to be fully demonstrated in this group. This divergence can be understood through differences in resource endowments and implementation capacity. Large enterprises typically possess greater financial resources, more mature digital infrastructure, and specialized technical teams, enabling them to effectively deploy AI solutions and translate them into operational resilience. On the other hand, SMEs often face difficult challenges—including limited capital, weaker IT systems, and a shortage of skilled personnel—that hinder their ability to integrate and leverage AI effectively. As a result, while AI holds theoretical promise for all firms, as a result, although AI has theoretical potential for all companies, it has real impact on resilience, which appears to be focused among larger organizations with more adequate resources in the Indonesian context.

Table 5. Heterogeneity Test Result

Variables	Big-Firm (1)	Small to Medium-Firm (2)	High-Digitalization (3)	Low-Digitalization (4)
AI	0.198*** (0.072)	0.015 (0.070)	0.260*** (0.079)	0.012 (0.068)
Constant	-0.908 (1.850)	-0.690 (1.618)	-3.423* (1.850)	-1.893 (1.637)
Controls Var	Yes	Yes	Yes	Yes
Firm & Year	Yes	Yes	Yes	Yes
Fisher’s Test	0.052		0.012	
Observations	1,290	1,175	1,415	1,050
R-squared	0.517	0.432	0.468	0.691

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

b. Digitalization Level

Following Maggio et al. (2024), we split the sample into high- and low-digitalization firms based on the median of an digitalization index. Columns (3) and (4) of Table 5 show that, for firms with high digitalization, the coefficient on AI penetration is positive and statistically significant, indicating a positive effect of AI on resilience. In contrast, for firms with low digitalization, the AI coefficient is positive but statistically insignificant, suggesting that the resilience-enhancing potential of AI has not yet been realized in this group. This pattern underscores the importance of complementary digital capabilities. Firms with high digitalization typically already possess robust data infrastructure, mature integration mechanisms, and a collection of digital talents—conditions that enable them to smoothly adopt AI into core operations and rapidly translate it into adaptive and recovery capacity. Conversely, firms with low digitalization often lack these foundational elements, facing significant barriers in absorbing, deploying,

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and scaling AI solutions. As a result, despite AI penetration, their ability to convert it into tangible resilience gains remains limited in the short to medium term.

Continued Table 5 Heterogeneity Test

Variables	Manufactur (1)	Non-Manufactur (2)
AI	0.171*** (0.063)	0.012 (0.070)
Constant	-1.793 (1.572)	-0.100 (1.605)
Controls Var	Yes	Yes
Firm & Year	Yes	Yes
Fisher's Test	0.073	
Observations	1,350	1,115
R-squared	0.577	0.580

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

c. Infrastructure Characteristic

Following Azemi & Khairunnisa (2025), we classify the sample into manufacturing and non-manufacturing firms based on the industry categorization of the Indonesia Stock Exchange (IDX). Columns (5) and (6) of Table 5 report the results. For manufacturing firms, the coefficient on AI penetration is positive and statistically significant, indicating that AI penetration meaningfully enhances firm resilience. In contrast, for non-manufacturing firms, the AI coefficient is positive but statistically insignificant, suggesting that the resilience benefits of AI have not yet emerged clearly in this group. This difference reflects fundamental differences in operational structure and data readiness. Manufacturing firms typically operate with standardized production processes, well-defined supply chain nodes, and rich streams of structured operational data—conditions that allow AI applications be rapidly deployed and yield tangible resilience gains. By contrast, non-manufacturing sectors—such as services, finance, or trade—feature more heterogeneous, interaction-intensive, and intangible business models, where value creation often hinges on human judgment, customer relationships, or context-specific knowledge. In these settings, integrating AI requires more complex customization, faces greater uncertainty in outcome measurement, and may involve longer gestation periods before resilience benefits realized. As a result, the short-term impact of AI on resilience in non-manufacturing companies remains limited.

E. Mechanism Test

To better understand the mechanisms behind how AI technology penetration enhances corporate resilience, this study follows He et al. (2025) and introduces broadband penetration (Broadband) as a mediating variable. Specifically, Broadband measures the level of digital infrastructure in the district or city where a firm is headquartered, proxied by fiber-optic network coverage, with data sourced from official Indonesian government statistics. A higher Broadband value indicates stronger regional digital infrastructure—characterized by faster data transmission speeds, greater network stability, and higher capacity—which provides the essential foundation for the smooth deployment and effective operation of data-intensive AI applications. Conversely, low Broadband levels reflect underdeveloped digital connectivity, which may act as a binding constraint on firms' ability to implement, scale, and benefit from AI technologies, thereby dampening the potential resilience gains from AI penetration. To formally test this channel, we estimate the following mediation model:

$$Broadband_{it} = \beta_0 + \beta_1 AI_{it} + \beta_2 Control_{it} + \delta_i + \mu_t + \epsilon_{it} \quad (3)$$

$$Resis_{it} = \phi_0 + \phi_1 AI_{it} + \phi_2 Broadband_{it} + \phi_3 Control_{it} + \delta_i + \mu_t + \epsilon_{it} \quad (4)$$

In Equation (3), i denotes the firm and t denotes the year; the dependent variable $Broadband_{it}$ represents the broadband penetration rate in the firm's location. In Equation (4), $Broadband_{it}$ is included as a mediating variable to test the transmission channel through which AI affects resilience. The model also controls for a set of firm-level covariates ($Control_{it}$), firm fixed effects (δ_i), to account for time-invariant unobserved heterogeneity, year fixed effects (μ_t) to absorb common time shocks, and a random error term (ϵ_{it})

Column (1) of Table 6 shows that AI penetration has a statistically significant positive effect on Broadband, indicating that greater AI penetration is associated with higher levels of local broadband infrastructure—either because AI-intensive firms locate in better-connected areas or because their presence stimulates digital infrastructure development. Column (2) further reveals that, after including Broadband in the regression, the coefficient on AI to resilience (Resis) decreases significantly, while Broadband itself exhibits a significant positive relationship with Resis. This pattern confirms that broadband penetration serves as a significant

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partial mediator in the link between AI technology penetration and firm resilience. In other words, AI enhances resilience not only through direct operational and strategic improvements but also indirectly—by being interrelated with, and partly reliant on, the quality of regional digital infrastructure. As firms deepen their use of AI, they both benefit from and contribute to the advancement of local broadband capabilities, which in turn strengthens their capacity to withstand and recover from external shocks (Hokmabadi et al., 2024). These findings highlight that robust digital infrastructure acts as a critical transmission channel and complementary condition for AI to realize its full resilience-enhancing potential. The results thus provide empirical support for Hypothesis 2.

Table 6. Mechanism Test Result

Variables	Broadband (1)	Resis (2)
AI	0.630*** (0.217)	0.160*** (0.053)
Broadband		0.011** (0.005)
Constant	1.768 (5.053)	-3.430** (1.243)
Controls Var	Yes	Yes
Firm & Year	Yes	Yes
Sobel Z value	2.731***	
Goodman-1	2.668***	
Goodman-2	2.801***	
Observations	2,465	2,465
R-squared	0.463	0.411

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

CONCLUSIONS

This study investigates the impact of AI technology penetration on firm resilience using a panel of Indonesian listed firms from 2016 to 2025. Our results provide three insights. First, AI penetration showing a robust and significantly positive effect on firm resilience. First, AI penetration exerts a robust and significantly positive effect on firm resilience. This result holds across multiple robustness checks—including alternative measures of both resilience and AI penetration, as well as models with high-dimensional fixed effects—confirming that AI serves as a credible driver of firms' capacity to absorb, adapt to, and recover from external shocks. Second, this effect is highly contingent on firm- and sector-level characteristics. The resilience-boosting role of AI is pronounced among large firms, highly digitalized firms, and manufacturing enterprises, where structured operations, data readiness, and scale facilitate effective AI integration. In contrast, the impact is statistically insignificant for SMEs, low-digitalization firms, and non-manufacturing sectors, suggesting that AI's benefits are not uniformly accessible and depend critically on complementary capabilities. Third, we identify regional broadband infrastructure as a key transmission channel: AI penetration not only directly enhances resilience but also Broadband thus acts as a partial mediator, underscoring that AI's effectiveness is embedded in a broader ecosystem of digital enablers.

These findings carry practical relevance. For firms, AI should be viewed as a strategic investment in long-term resilience. Large and digitally advanced firms are well-positioned to deepen AI integration, while SMEs must first strengthen foundational elements—such as data governance, digital talent, and process standardization—before AI can deliver tangible returns. For policymakers, a one-size-fits-all approach is inadequate. Support should be differentiated: incentivize AI penetration among frontrunners through tax or R&D credits, while simultaneously investing in broadband expansion and digital capacity-building in underserved regions to level the playing field. For investors, AI maturity and digital readiness should be incorporated into risk and valuation models—firms with strong AI capabilities are likely to demonstrate superior resilience and growth potential in unstable environments.

Limitations and future research directions are also noteworthy. First, our AI measure relies on R&D intensity—a useful but indirect proxy; future studies would benefit from granular, direct data on AI spending or deployment. Second, the sample is limited to listed firms, raising questions about generalizability to private or micro-enterprises. Third, while we validate broadband as a key mediator, deeper organizational mechanisms—such as AI-driven learning, dynamic capability reconfiguration, or workforce adaptation—remain underexplored. Finally, our context is Indonesia, a high-volatility emerging market; cross-national comparisons could reveal how institutional, regulatory, or cultural differences shape the AI–resilience relationship.

The Impact of Artificial Intelligence Technology Penetration on Corporate Resilience: Empirical Evidence from Indonesian Listed Companies

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