INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN BUSINESS & SOCIAL SCIENCES

Vol 16, Issue 11, (2026) E-ISSN: 2222-6990

The Impact of Enterprise Risk Management on Firm Performance: The Moderating Role of Artificial Intelligence Disclosure

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DOI Link: http://dx.doi.org/10.6007/IJARBSS/v16-i11/29477

Published Date: 24 November 2026

Abstract

This study examines the relationship between enterprise risk management (ERM) and firm performance and investigates whether artificial intelligence (AI) disclosure influences this relationship in Indonesian non-financial listed firms. This study uses panel data from 471 Indonesian non-financial listed firms during 2019–2023, comprising 2,355 firm-year observations. Firm performance is measured by return on equity (ROE), ERM is proxied by an Advanced ERM indicator, and AI disclosure is measured using the frequency of AI-related terms in annual reports. The hypotheses are tested using ordinary least squares (OLS) regression with firm-level clustered standard errors, year fixed effects, and industry fixed effects, while generalized least squares (GLS) and coarsened exact matching (CEM) are used for robustness checks. The results show that ERM has a positive association with ROE, although the strength of the evidence varies across model specifications. AI disclosure is positively and significantly associated with ROE, suggesting that firms with greater AI-related disclosure tend to report higher financial performance. However, the negative interaction between ERM and AI disclosure indicates that AI disclosure attenuates, rather than strengthens, the positive association between ERM and firm performance. These findings suggest that AI disclosure does not automatically complement ERM unless AI-related initiatives are supported by adequate data governance, technological infrastructure, managerial readiness, and employee capabilities. This study contributes to the ERM and digital disclosure literature by examining AI disclosure as both a performance-related factor and a contextual factor in the relationship between ERM and firm performance, providing evidence from Indonesian non-financial listed firms.

Keywords: Enterprise Risk Management, Artificial Intelligence Disclosure, Firm Performance, Return on Equity, Indonesian Non-Financial Firms

Introduction

Enterprise risk management (ERM) has become an important governance mechanism for firms operating in increasingly uncertain business environments. Firms today face not only financial and operational risks, but also regulatory pressure, reputational exposure, supply chain disruption, technological change, and increasing stakeholder demands for transparent governance. In this context, risk management can no longer be treated as a fragmented or compliance-oriented function. Instead, it is expected to support strategic decision-making, improve accountability, and help firms preserve and create value for shareholders and other stakeholders (Chairani & Siregar, 2021; Ghazieh & Chebana, 2021).

Major corporate failures have reinforced the importance of integrated risk governance. The Enron collapse, for instance, showed how weak governance, poor transparency, and inadequate risk oversight can destroy firm value and public trust. Similar concerns have also emerged in Indonesia, as reflected in the case of PT Garuda Indonesia, where financial reporting issues and governance weaknesses damaged corporate credibility and attracted regulatory sanctions (Tang & Fiorentina, 2021). These cases indicate that risk management is not merely a technical process, but an essential part of corporate governance and long-term business sustainability.

ERM is expected to improve firm performance because it enables firms to identify, assess, prioritize, and respond to risks in a more coordinated manner. By integrating risk information across business units, ERM can improve capital allocation, support internal control, reduce volatility, and strengthen managerial decision-making (Farrell & Gallagher, 2019; Saeidi et al., 2021). Several studies suggest that ERM is positively associated with firm performance and firm value (Anugerah et al., 2023; Chairani & Siregar, 2021; Horvey & Odei-Mensah, 2024; Malik et al., 2020). However, the empirical evidence remains inconclusive. Some studies report negative, insignificant, or indirect relationships between ERM and performance, indicating that the effectiveness of ERM may depend on other organizational conditions (Rahman et al., 2022; Ricardianto et al., 2023).

At the same time, artificial intelligence (AI) has become increasingly relevant in corporate digital transformation. AI-related technologies can support automation, data processing, predictive analytics, fraud detection, knowledge sharing, and more responsive decision-making (Olan et al., 2022; Sullivan & Wamba, 2024). More broadly, digital transformation may enhance firm performance by improving strategic effectiveness and internal control mechanisms (Xu et al., 2024). AI-related disclosure in annual reports may also signal firms' digital orientation, technological awareness, and managerial attention toward technology-based transformation (Lui, 2026; Shiyyab et al., 2023). However, AI disclosure does not necessarily indicate the actual implementation or maturity of AI systems. It may also reflect corporate communication, strategic signalling, or early-stage digital orientation.

Recent studies further show that AI-related disclosure and AI adoption are increasingly relevant to corporate reporting, risk management, and firm performance. Alzeghoul and Alsharari (2025) show that AI disclosure is related to financial reporting and performance outcomes, while Yang and Zhou (2025) suggest that AI adoption can improve the quality of corporate accounting information disclosure. In addition, Wang and Yang (2026) highlight that digital intelligence transformation is associated with the effectiveness of enterprise risk

management. These studies indicate that AI-related disclosure is not only a technological issue, but also a governance, reporting, and performance-related issue.

Despite the growing literature on ERM and firm performance, the research gap remains in how AI disclosure shapes this relationship. Prior studies have provided important evidence on ERM as a governance mechanism that is associated with firm performance and firm value through stronger risk governance, internal control, and managerial decision-making (Anugerah et al., 2023; Chairani & Siregar, 2021; Farrell & Gallagher, 2019; Saeidi et al., 2021). Other studies have examined digital transformation, AI-related disclosure, and AI adoption as separate factors associated with firm performance, disclosure quality, innovation, and strategic responsiveness (Alzeghoul & Alsharari, 2025; Shiyyab et al., 2023; Sullivan & Wamba, 2024; Yang & Zhou, 2025). Recent evidence also suggests that digital transformation may influence firm performance through ERM-related mechanisms, such as strategic effectiveness, internal control, and risk management effectiveness (Wang & Yang, 2026; Xu et al., 2024).

However, these studies have generally examined ERM, digital transformation, and AI disclosure separately. Limited evidence explains whether AI disclosure changes the strength or direction of the relationship between ERM and firm performance, particularly in emerging market settings. This gap is important because AI disclosure may reflect firms' digital orientation and technological awareness, but it may not necessarily indicate actual AI implementation or AI maturity. Therefore, AI disclosure may complement ERM by supporting information processing, automation, and strategic responsiveness, or it may weaken the performance benefits of ERM if it reflects early-stage digital communication without sufficient organizational readiness, data governance, technological infrastructure, employee capability, and managerial support (Marioni et al., 2024; Olan et al., 2022; Shi et al., 2025).

The Indonesian context provides a relevant setting for examining this issue. As an emerging market, Indonesia has experienced increasing attention to corporate governance, risk management, and digital transformation (Laila et al., 2021; Tanjung, 2020; Xu et al., 2024). However, the development of ERM practices and AI-related disclosure remains uneven across firms, particularly among non-financial listed companies (Anugerah et al., 2023; Chairani & Siregar, 2021; Shiyyab et al., 2023). This makes Indonesia an important context for understanding whether AI disclosure complements or constrains the relationship between ERM and firm performance.

This study addresses this gap by examining the relationship between ERM and firm performance and investigating whether AI disclosure influences this relationship among Indonesian non-financial listed firms. Specifically, this study asks whether ERM is associated with firm performance, whether AI disclosure is associated with firm performance, and whether AI disclosure moderates the relationship between ERM and firm performance. Using panel data from 471 non-financial companies listed on the Indonesia Stock Exchange (IDX) during 2019-2023, resulting in 2,355 firm-year observations, this study provides evidence on how ERM and AI disclosure are associated with return on equity (ROE). ERM is proxied by an Advanced ERM indicator, while AI disclosure is measured based on the frequency of AI-related terms disclosed in annual reports.

This study contributes to the literature in three ways. First, it extends prior ERM research by examining whether ERM is associated with firm performance in Indonesian non-financial listed firms. Second, it contributes to the AI disclosure and digital transformation literature by examining whether AI-related disclosure is associated with firm performance. Third, it provides new evidence by examining AI disclosure as a moderating factor in the ERM-firm performance relationship. This contribution is important because it shows whether digital orientation, as reflected in AI disclosure, complements or constrains the performance benefits of ERM in an emerging market setting.

Literature Review

Theoretical Background

This study is grounded in agency theory and the resource-based view. Agency theory explains the relationship between shareholders as principals and managers as agents, where agency problems may arise when managers have incentives to pursue private interests or when information asymmetry limits shareholders' ability to monitor managerial actions (Jensen & Meckling, 1976). In this context, ERM can reduce agency problems by improving transparency, strengthening internal control, and supporting more accountable decision-making (Horvey & Odei-Mensah, 2024; Saeidi et al., 2021). ERM therefore functions as a governance mechanism that helps align managerial decisions with shareholder interests.

AI disclosure is also relevant to agency theory because corporate disclosure can reduce information asymmetry between firms and stakeholders (Healy & Palepu, 2001). When firms disclose AI-related initiatives, they communicate information about digital orientation, innovation, and technological awareness. Such disclosure may also serve as a signal of firms' technological orientation and strategic responsiveness (Shiyyab et al., 2023). However, disclosure that is not supported by actual readiness may create a gap between corporate communication and organizational implementation.

The resource-based view argues that firms achieve competitive advantage when they possess valuable, rare, inimitable, and well-organized resources and capabilities (Barney, 1991; Cruz & Haugan, 2019). ERM can be viewed as an organizational capability because it reflects a firm's ability to manage uncertainty through integrated risk governance. AI-related orientation can also represent a potential strategic capability when it enhances data processing, innovation, and decision-making (Olan et al., 2022; Sullivan & Wamba, 2024). From this perspective, ERM and AI disclosure may support firm performance when they are effectively aligned with firm resources, systems, and managerial capabilities.

Enterprise Risk Management and Firm Performance

ERM is an integrated approach that enables firms to identify, assess, manage, and monitor risks across organizational activities (Florio & Leoni, 2017). Unlike traditional risk management, which often focuses on specific risks or individual business units, ERM provides a more comprehensive view of risk and supports better coordination in managerial decision-making. From an agency theory perspective, ERM can strengthen governance mechanisms by improving transparency, internal control, and accountability. This may reduce information asymmetry and help align managerial actions with shareholder interests (Jensen & Meckling, 1976; Saeidi et al., 2021).

ERM is expected to improve firm performance because it supports more effective risk identification, resource allocation, strategic planning, and operational control. Firms with more advanced ERM practices are better able to anticipate uncertainties, reduce performance volatility, and respond to internal and external risks in a coordinated manner. Prior studies generally suggest that ERM is positively associated with firm performance and firm value, as effective risk governance can improve decision quality and support value creation (Anugerah et al., 2023; Chairani & Siregar, 2021; Farrell & Gallagher, 2019; Horvey & Odei-Mensah, 2024; Malik et al., 2020; Saeidi et al., 2021).

However, empirical findings on the ERM-performance relationship remain inconclusive. Some studies report negative, insignificant, or indirect effects, suggesting that the benefits of ERM may depend on how effectively risk management practices are implemented and integrated into organizational processes (Rahman et al., 2022; Ricardianto et al., 2023). Despite these mixed findings, this study argues that firms with more advanced ERM practices are more likely to report stronger performance. From an agency theory perspective, ERM may reduce agency problems by improving transparency, monitoring, internal control, and managerial accountability. From a resource-based view perspective, ERM may also function as an organizational capability that helps firms manage uncertainty and coordinate risk responses. Therefore, ERM is expected to be positively associated with firm performance.
H1: Enterprise risk management is positively associated with firm performance.

Artificial Intelligence Disclosure and Firm Performance
AI disclosure reflects the extent to which firms communicate AI-related initiatives, digital orientation, and technological awareness in their corporate reports. In this study, AI disclosure is not interpreted as direct evidence of AI implementation, but as a disclosure-based indicator of firms' attention to AI-related transformation. From a disclosure perspective, firms may use annual reports to communicate strategic priorities, innovation orientation, and technological readiness to stakeholders. Such disclosure can reduce information asymmetry and provide signals about a firm's ability to respond to technological change (Healy & Palepu, 2001; Shiyyab et al., 2023).

AI-related orientation may contribute to firm performance through several mechanisms. AI technologies can support data processing, automation, predictive analytics, knowledge sharing, and faster decision-making, which may improve operational efficiency and strategic responsiveness (Olan et al., 2022; Sullivan & Wamba, 2024). Firms that disclose more AI-related information may also be perceived as more innovative and adaptive to changes in the business environment. Prior studies suggest that AI-related capabilities and disclosure are associated with financial performance because they reflect innovation capacity, digital transformation, and the ability to use technology to support business processes (Alzeghoul & Alsharari, 2025; Marioni et al., 2024; Shiyyab et al., 2023; Sullivan & Wamba, 2024; Yang & Zhou, 2025).

Although AI disclosure does not necessarily indicate the maturity of AI implementation, it may still provide useful information about firms' strategic attention to digital transformation. From an agency theory perspective, AI disclosure may reduce information asymmetry by communicating firms' technological orientation, innovation attention, and responsiveness to stakeholders. From a resource-based view perspective, AI-related orientation may reflect

potential digital capability that supports information processing, innovation, and decision-making. Therefore, this study expects AI disclosure to be positively associated with firm performance.

H2: Artificial intelligence disclosure is positively associated with firm performance.

The Moderating Role of AI Disclosure in the Relationship between ERM and Firm Performance

The relationship between ERM and firm performance may depend on the extent to which firms are able to align risk management practices with broader organizational capabilities. From an agency theory perspective, ERM may strengthen monitoring, accountability, and internal control, but its performance implications may be stronger when firms also provide more transparent information about their technological orientation and digital initiatives. AI disclosure may reduce information asymmetry by communicating firms' attention to AI-related transformation, digital risks, and technology-enabled decision-making. Therefore, AI disclosure may support the governance role of ERM by improving stakeholders' understanding of how firms manage risk in a more technology-oriented business environment.

From a resource-based view perspective, ERM can be viewed as an organizational capability because it reflects a firm's ability to identify, assess, and respond to uncertainty in an integrated manner. AI-related orientation may also represent a potential digital capability because it is associated with data processing, predictive analytics, automation, and more responsive decision-making (Olan et al., 2022; Sullivan & Wamba, 2024). When these capabilities are aligned, firms may be better able to process risk information, identify emerging risks, and respond to uncertainty more effectively. Prior research also suggests that digital transformation can be associated with firm performance through stronger strategic effectiveness, internal control mechanisms, and risk management effectiveness (Wang & Yang, 2026; Xu et al., 2024).

Accordingly, AI disclosure may strengthen the relationship between ERM and firm performance because it reflects firms' digital orientation and technological awareness that may complement risk governance practices. However, this complementary effect depends on whether AI-related orientation is supported by appropriate organizational resources, systems, data assets, managerial capability, and organizational integration (Barney, 1991; Olan et al., 2022; Shi et al., 2025). When ERM and AI-related orientation are effectively aligned, firms may obtain greater performance benefits from risk management because they can combine risk governance with stronger information-processing and decision-making capabilities.

H3: Artificial intelligence disclosure strengthens the positive relationship between enterprise risk management and firm performance.

Method

Research Design and Sample

This study applies a quantitative research design using secondary data obtained from the annual reports of firms listed on the IDX. The sample consists of non-financial companies listed on the IDX during 2019-2023. Non-financial firms are selected because they represent a broad range of business activities in the Indonesian economy and are exposed to diverse operational, regulatory, technological, and market risks (Florio & Leoni, 2017; Laila et al.,

2021). The 2019-2023 period is considered relevant because it captures recent developments in risk governance and digital transformation, including increasing attention to technology-related disclosure in the post-pandemic business environment (Al-ahdal et al., 2024; Sullivan & Wamba, 2024; Xu et al., 2024).

The sample selection process began with 661 companies identified from IDX listings during the 2019–2023 period. Companies classified under the financial industry classification were excluded because they operate under different regulatory frameworks, capital structures, and risk management requirements, which may limit comparability with non-financial firms (Florio & Leoni, 2017; Soewarno & Tjahjadi, 2020). Companies with incomplete annual report availability during the observation period were also excluded because annual reports were required to measure ERM and AI disclosure consistently. In addition, companies with incomplete or unusable information for the research variables were excluded. Firms with no AI-related keyword disclosure were retained and coded as zero, provided that their annual reports were available and processable. The final sample consisted of 471 Indonesian non-financial listed firms, resulting in 2,355 firm-year observations.

Table 1
Sample Selection Process

Sample selection process	**Number of companies**	**Firm-year observations**
Companies identified from IDX listings during 2019–2023	661	3,305
Less: Companies classified under the financial industry classification	(99)	(495)
Less: Companies with incomplete annual report availability during 2019–2023	(54)	(270)
Less: Companies with incomplete or unusable information for research variables	(37)	(185)
Final sample	471	2,355

All data are collected from firms' annual reports, including information on ERM, AI disclosure, and financial variables. Annual reports are used because they provide publicly available and comparable information on corporate governance, risk management practices, technology-related disclosure, and financial performance (Chairani & Siregar, 2021; Shiyyab et al., 2023).

Variable Measurement

The dependent variable in this study is firm performance, measured using ROE. ROE is calculated as net income divided by total equity and reflects the extent to which firms generate returns for shareholders (Amin & Aslam, 2017; Chairani & Siregar, 2021).

The main independent variable is ERM, proxied by an Advanced ERM indicator. This indicator captures the extent to which firms disclose advanced risk governance, risk assessment practices, and recognized ERM frameworks. Following prior ERM measurement approaches, ERM is assessed using eight components: the existence of a risk management director or chief risk officer, the establishment of a risk committee, risk committee reporting to the board of directors, frequency of risk assessment, level of risk assessment, risk assessment method, the

use of COSO as an ERM framework, and the use of ISO as an ERM framework (Chairani & Siregar, 2021; Florio & Leoni, 2017). The eight ERM criteria and coding rules are presented in Table 3.

AI disclosure is measured using a keyword-based content analysis of annual reports. The initial keyword list was adapted from Shiyyab et al. (2023). In this study, AI disclosure is not interpreted as direct evidence of actual AI implementation or AI maturity. Instead, it is interpreted as a disclosure-based proxy for firms' AI-related digital orientation and technological awareness.

The keyword list includes explicit AI-related terms, such as artificial intelligence, machine learning, deep learning, augmented intelligence, natural language processing, robotics, and robots. It also includes broader digital technology terms, such as electronic payment, blockchain, digital services, information security, and cybersecurity, because these terms may reflect the digital infrastructure, data systems, automation environment, and security readiness that support AI-related transformation. These broader terms are therefore not treated as direct measures of AI adoption, but as indicators of the digital capability environment within which AI-related initiatives may develop.

The AI disclosure data were collected from English-language annual reports. The annual reports were processed using Python to extract text and calculate the total frequency of the selected keywords. Each occurrence of a keyword from the final list was counted as one disclosure frequency because this study aims to capture disclosure intensity rather than only the presence or absence of disclosure. Therefore, repeated occurrences of the selected keywords were counted as part of the total AI disclosure frequency.

After the automated keyword extraction, selected annual reports were manually reviewed to assess whether the keyword list captured AI-related digital disclosure in a reasonable manner. This manual review was used as a validation step for the keyword list, not as the main counting method. Accordingly, although the variable is labelled as AI disclosure, it should be interpreted as a disclosure-based proxy for firms' AI-related digital orientation and technological awareness, rather than direct evidence of actual AI implementation or AI maturity.

Leverage, innovation, and firm age are included as control variables. Leverage is measured as total liabilities divided by total equity, innovation is measured as research and development expenditure divided by total sales, and firm age is measured as the observation year minus the company's listing year (Amin & Aslam, 2017; Florio & Leoni, 2017; Septyanto & Nugraha, 2021; Shiyyab et al., 2023).

Table 2
Variable Measurement

Variable	Symbol	Type	Measurement	Source
Firm Performance	ROE	Dependent variable	Net income divided by total equity.	Amin & Aslam (2017); Chairani & Siregar (2021)
Enterprise Risk Management	ADVERM	Independent variable	Dummy variable equal to 1 if the firm obtains an ERM score of at least four out of eight ERM components, and 0 otherwise. The eight components and coding rules are presented in Table 3.	Chairani & Siregar (2021); Florio & Leoni (2017)
Artificial Intelligence Disclosure	AI	Independent and moderating variable	Total frequency of AI-related keywords disclosed in annual reports, calculated using Python-based keyword extraction. The keyword list is presented in Table 4.	Shiyyab et al. (2023)
Leverage	LEV	Control variable	Total liabilities divided by total equity.	Florio & Leoni, (2017); Septyanto & Nugraha (2021)
Innovation	INNOV	Control variable	Research and development expenditure divided by total sales.	Amin & Aslam (2017)
Firm Age	AGE	Control variable	Number of years since the company was listed on the Indonesia Stock Exchange, calculated as the observation year minus the listing year.	Shiyyab et al. (2023)

Table 3
ERM Criteria and Coding

Code	ERM Criterion	Coding Rule
CRO	Risk management director or chief risk officer	1 if the company has a risk management director or chief risk officer, and 0 otherwise.
RISKCOM	Risk committee	1 if the company has established a risk committee, and 0 otherwise.
RCTOBOD	Risk committee reporting to the board of directors	1 if the corporate governance body responsible for risk management, such as a specific risk committee, internal control and risk committee, or internal control committee, reports to the board of directors at least twice a year, and 0 otherwise.
RAFREQ	Frequency of risk assessment	1 if the company carries out risk assessment at least twice a year, and 0 otherwise.
RALEVEL	Risk assessment level	1 if the company carries out risk assessment procedures on an ongoing basis down to the lowest level of the company, such as business units or functions, and 0 otherwise.
RAMETHOD	Risk assessment method	1 if the company adopts specific qualitative and quantitative risk assessment methods, and 0 otherwise.
COSO	COSO ERM framework	1 if the company uses COSO as the ERM framework, and 0 otherwise.
ISO	ISO ERM framework	1 if the company uses ISO as the ERM framework, and 0 otherwise.

Notes: Each ERM component is coded as 1 if the relevant ERM practice is disclosed in the annual report and 0 otherwise. The ERM score is calculated by summing the eight components. ADVERM is coded as 1 if the company obtains an ERM score of at least four out of eight components, and 0 otherwise.

Table 4
AI Disclosure Keywords

Category	Keywords
Digital Awareness, Transformation, and Capabilities	Digital Transformation, Fintech, Financial Technology, Modern Technology, AI, Digital Strategy, Latest Technology, Advanced Technology, AI Computing Technology, Digital Infrastructure, Digital Library, Electronic Channel, Electronic System, Internet Of Things, 5g Technology, Advanced Technical Experiences, Digital Platform, Digital Technology, 5g Networks, Blockchain, Smart Connection, Digital Awareness, Digital Capabilities, Digital Culture, Digital Economy, Digital Futuristic, Digital Transition, Augmented Reality Technology, Technical Platform, Web Technology, Machine Learning, Deep Learning, Augmented Intelligence, Natural Language Processing (NLP).
AI Application, Product, Service, and Process	Robotics, Automation, Digital Services, Mobile Apps, Electronic Payment, Mobile Payment, Robots, Digital Payment, Digital Identity, Smartphones, Digital Product, Electronic Service, Intelligently Analyses, Digital Wallet, Electronic Wallet, Mobile Device Service.
AI Information Challenges and Cyber Security Threats	Information Security, Cyber Security, Electronic Security, IT Risks Security, Electronic Security Policies, Card Security, Cyber Risk, Electronic Security, Cybercrime, Customized Electronic Security Methods, Cyber Breach, Cyber Resiliency, Defense Technology, Cyber Intelligence, Electronic Attack, Global Security, Information Security Breaches, Security Vulnerabilities.

Empirical Model and Data Analysis

Before estimating the regression models, continuous variables are winsorized at the 1st and 99th percentiles to reduce the influence of extreme values. The descriptive statistics, correlation analysis, and regression models are reported based on the winsorized data. The hypotheses are tested using ordinary least squares (OLS) regression with firm-level clustered standard errors, year fixed effects, and industry fixed effects. Year fixed effects are included to control for macroeconomic and time-specific influences, while industry fixed effects are included to control for sectoral differences. Firm-level clustered standard errors are used to account for potential correlation of errors within the same company over time. For the regression analysis, AI disclosure is mean-centered before creating the interaction term. The interaction term is calculated as ADVERM multiplied by centered AI disclosure. The original AI disclosure variable is reported in the descriptive statistics and correlation matrix for ease of interpretation. The following regression models are estimated:

$$ROE_{it} = \alpha_0 + \beta_1 ADVERM_{it} + \beta_2 AI_C_{it} + \beta_3 LEV_{it} + \beta_4 INNOV_{it} + \beta_5 AGE_{it} + Year\ FE + Industry\ FE + \varepsilon_{it} \quad (1)$$

$$ROE_{it} = \alpha_0 + \beta_1 ADVERM_{it} + \beta_2 AI_C_{it} + \beta_3 (ADVERM_{it} \times AI_C_{it}) + \beta_4 LEV_{it} + \beta_5 INNOV_{it} + \beta_6 AGE_{it} + Year\ FE + Industry\ FE + \varepsilon_{it} \quad (2)$$

where ROE represents firm performance, ADVERM represents the Advanced ERM indicator, AI_C represents centered AI disclosure, LEV represents leverage, INNOV represents innovation, AGE represents firm age, i represents the firm, t represents the year, and ε represents the error term. Model 1 tests the direct associations of ERM and AI disclosure with firm performance, while Model 2 tests the moderating role of AI disclosure in the relationship between ERM and firm performance. Robustness checks are conducted using generalized least squares (GLS) and coarsened exact matching (CEM) to assess the consistency of the main findings.

For the CEM robustness test, ADVERM is treated as the treatment variable. Firms with and without advanced ERM practices are matched based on leverage, innovation, firm age, year, and industry. Leverage, innovation, and firm age are coarsened into seven groups, while year and industry are treated as categorical matching variables. The regression models are then re-estimated using the matched sample and CEM weights.

Findings

Descriptive Statistics

Table 5 presents the descriptive statistics for the variables used in this study. The sample consists of 2,355 firm-year observations. The mean value of ROE is 0.030, indicating that Indonesian non-financial listed firms generate an average return on equity of approximately 3.0%. The standard deviation of ROE is 0.368, with values ranging from -2.161 to 1.400, suggesting considerable variation in firm performance across the sample.

The mean value of ADVERM is 0.180, indicating that approximately 18% of the firm-year observations meet the criteria for advanced ERM practices. This suggests that advanced ERM implementation remains relatively limited among Indonesian non-financial listed firms. AI disclosure has a mean value of 7.542 and a standard deviation of 15.425, with a maximum value of 91.000. This indicates that AI-related disclosure varies substantially across firms, reflecting uneven levels of digital orientation and technology-related communication in annual reports.

The mean leverage value is 1.159, suggesting that, on average, firms have liabilities exceeding their equity. The minimum leverage value is negative, which may reflect firms with negative equity during the observation period. Innovation has a mean value of 0.001 and a maximum value of 0.032, indicating that research and development expenditure remains relatively low among the sampled firms. Firm age has a mean value of 15.687 and a standard deviation of 11.005, with values ranging from 0.000 to 40.000. This suggests that the sample includes both newly listed and more mature firms, reflecting variation in firm maturity across Indonesian non-financial listed companies.

Table 5
Descriptive Statistics

	N	Mean	Std. Dev.	Minimum	Maximum
ROE	2355	0.030	0.368	-2.161	1.400
ADVERM	2355	0.180	0.385	0.000	1.000
AI	2355	7.542	15.425	0.000	91.000
LEV	2355	1.159	2.509	-6.301	17.211
INNOV	2355	0.001	0.004	0.000	0.032
AGE	2355	15.687	11.005	0.000	40.000

Notes: ROE represents return on equity; ADVERM represents the Advanced ERM indicator; AI represents AI disclosure; LEV represents leverage; INNOV represents innovation; and AGE represents firm age. Continuous variables are winsorized at the 1st and 99th percentiles.

Correlation Analysis

Table 6 presents the correlation matrix among the variables used in this study. The results show that ADVERM is positively correlated with ROE at the 10% significance level, indicating that firms with more advanced ERM practices tend to report higher firm performance. AI disclosure is positively correlated with ROE, although the relationship is not statistically significant.

ADVERM is positively and significantly correlated with AI disclosure, suggesting that firms with more advanced ERM practices also tend to provide greater AI-related disclosure. Leverage shows a negative and significant correlation with ROE, indicating that firms with higher leverage tend to report lower firm performance. However, leverage is positively and significantly correlated with both ADVERM and AI disclosure, suggesting that firms with higher debt exposure may have greater incentives to strengthen risk management practices and disclose technology-related initiatives.

Innovation is positively and significantly correlated with ROE, ADVERM, and AI disclosure. This indicates that firms with higher innovation intensity tend to perform better, implement more advanced ERM practices, and disclose more AI-related information. However, the correlation between innovation and leverage is negative but not statistically significant.

Firm age is positively correlated with ROE, ADVERM, and AI disclosure at the 10% significance level. This suggests that older listed firms tend to report slightly higher firm performance, have more advanced ERM practices, and provide greater AI-related disclosure. Firm age is also positively and significantly correlated with innovation at the 5% significance level, indicating that more mature firms may have greater innovation-related activities. However, the correlation between firm age and leverage is positive but not statistically significant.

Overall, the correlation coefficients do not indicate serious multicollinearity concerns, as the highest absolute correlation is between leverage and ROE at 0.513, which remains below commonly used threshold levels. The correlations between firm age and the other variables are relatively low, suggesting that the inclusion of firm age does not create multicollinearity concerns. Therefore, the variables are considered suitable for further regression analysis.

Table 6
Pearson Correlation

	ROE	ADVERM	AI	LEV	INNOV	AGE
ROE	1.000					
ADVERM	0.034*	1.000				
	(0.097)					
AI	0.031	0.247***	1.000			
	(0.127)	(0.000)				
LEV	-0.513***	0.060***	0.061***	1.000		
	(0.000)	(0.004)	(0.003)			
INNOV	0.069***	0.048**	0.054***	-0.008	1.000	
	(0.001)	(0.021)	(0.009)	(0.702)		
AGE	0.034*	0.036*	0.040*	0.008	0.044**	1.000
	(0.098)	(0.077)	(0.051)	(0.716)	(0.033)	

Notes: This table reports the Pearson correlation coefficients among the variables used in this study. ROE represents return on equity; ADVERM represents the Advanced ERM indicator; AI represents artificial intelligence disclosure; LEV represents leverage; INNOV represents innovation and AGE represents firm age. P-values are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Continuous variables are winsorized at the 1st and 99th percentiles.

Regression Results

Table 7 presents the OLS regression results for the relationship between ERM, AI disclosure, and firm performance. Model 1 examines the direct associations of ADVERM and AI disclosure with ROE, while Model 2 includes the interaction term between ADVERM and centered AI disclosure.

In Model 1, ADVERM has a positive coefficient, but it is not statistically significant. This indicates that firms with advanced ERM practices do not report significantly higher ROE in the direct-effect model. However, AI disclosure is positive and significant at the 10% level, suggesting that firms with higher AI-related disclosure tend to report higher firm performance. Leverage is negative and significant at the 1% level, indicating that firms with higher leverage tend to have lower ROE. Innovation and firm age are positive but not statistically significant.

In Model 2, ADVERM becomes positive and significant at the 10% level. Since AI disclosure is mean-centered, the coefficient of ADVERM represents the association between advanced ERM and ROE when AI disclosure is at its average level. The result suggests that firms with advanced ERM practices tend to report higher firm performance when AI disclosure is at the mean. AI disclosure remains positive and significant at the 5% level, indicating that AI-related disclosure is positively associated with ROE.

The interaction term between ADVERM and centered AI disclosure is negative and significant at the 5% level. This finding indicates that AI disclosure weakens the positive association between advanced ERM and firm performance. Therefore, the result does not support the hypothesis that AI disclosure strengthens the relationship between ERM and firm

performance. One possible explanation is that AI-related disclosure may reflect early-stage technological orientation or strategic communication rather than fully developed AI implementation that is effectively integrated with ERM practices.

Among the control variables, leverage remains negative and significant across both models, while innovation and firm age are not statistically significant. The adjusted R-squared values are 0.281 in Model 1 and 0.283 in Model 2, suggesting that the inclusion of the interaction term slightly improves the explanatory power of the model.

Table 7
Regression Results

	(1) **ROE**	**(2)** **ROE**
ADVERM	0.043	0.054*
	(1.57)	(1.93)
AI (centered)	0.001*	0.002**
	(1.92)	(2.46)
ADVERM × AI (centered)		-0.002**
		(-2.26)
LEV	-0.077***	-0.077***
	(-9.29)	(-9.33)
INNOV	4.783	4.752
	(0.87)	(0.88)
AGE	0.001	0.001
	(1.01)	(0.98)
Constant	0.148***	0.151***
	(3.78)	(3.90)
Industry FE	Yes	Yes
Year FE	Yes	Yes
F	10.993	10.594
Adjusted R-squared	0.281	0.283
N	2355	2355

Notes: This table reports the OLS regression results. The dependent variable is ROE. ADVERM represents the Advanced ERM indicator; AI represents artificial intelligence disclosure; LEV represents leverage; INNOV represents innovation; and AGE represents firm age. Model 1 examines the direct associations of ADVERM and AI disclosure with ROE, while Model 2 includes the interaction term between ADVERM and AI disclosure. Year and industry fixed effects are included as indicated. The t-statistics are reported in parentheses and are based on firm-level clustered standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Continuous variables are winsorized at the 1st and 99th percentiles.

Robustness Tests

To assess the stability of the main findings, this study conducts two robustness tests. First, GLS is employed as an alternative estimation approach to examine whether the results remain consistent when potential heteroskedasticity and correlation in the panel data structure are considered (Wooldridge, 2024). Second, coarsened exact matching (CEM) is applied to reduce covariate imbalance between firms with and without advanced ERM practices (Iacus et al.,

2012). This sequence allows the study to evaluate robustness from both estimation and sample comparability perspectives.

Table 8 presents the GLS robustness test. The results are generally consistent with the main regression findings. In Model 1, ADVERM is positive and significant at the 1% level, indicating that firms with advanced ERM practices are associated with higher ROE. AI disclosure is also positive and significant at the 1% level, suggesting that firms with higher AI-related disclosure tend to report higher firm performance.

In Model 2, ADVERM and AI disclosure remain positive and significant at the 1% level. The interaction term between ADVERM and centered AI disclosure is negative and significant at the 1% level. This result is consistent with the main regression and indicates that AI disclosure weakens, rather than strengthens, the positive association between advanced ERM practices and firm performance.

Among the control variables, leverage remains negative and significant, while innovation and firm age are positive and significant. Overall, the GLS results support the robustness of the main findings after considering an alternative estimation approach.

Table 8
GLS Robustness Test

	(1) **ROE**	**(2)** **ROE**
ADVERM	0.037***	0.044***
	(7.60)	(8.88)
AI (centered)	0.001***	0.001***
	(4.99)	(5.91)
ADVERM × AI (centered)		-0.001***
		(-2.87)
LEV	-0.073***	-0.074***
	(-30.29)	(-30.38)
INNOV	1.323**	1.774***
	(2.50)	(3.15)
AGE	0.001***	0.001***
	(3.63)	(4.19)
Constant	0.123***	0.125***
	(11.65)	(12.09)
Year FE	Yes	Yes
Industry FE	Yes	Yes
N	2355	2355

Notes: This table reports the GLS robustness test results. The dependent variable is ROE. ADVERM represents the Advanced ERM indicator; AI represents artificial intelligence disclosure; LEV represents leverage; INNOV represents innovation; and AGE represents firm age. Model 1 examines the direct associations of ADVERM and AI disclosure with ROE, while Model 2 includes the interaction term between ADVERM and AI disclosure. Year and industry fixed effects are included as indicated. The t-statistics are reported in parentheses and are based on firm-level clustered standard errors. *, **, and *** indicate significance at the 10%,

5%, and 1% levels, respectively. Continuous variables are winsorized at the 1st and 99th percentiles.

Table 9 presents the CEM robustness test based on the matched sample. The results remain generally consistent with the main regression findings. In Model 1, ADVERM is positive and significant at the 1% level, indicating that firms with advanced ERM practices are associated with higher ROE after improving covariate balance through CEM. AI disclosure is also positive and significant at the 1% level, suggesting that firms with higher AI-related disclosure tend to report higher firm performance.

In Model 2, ADVERM remains positive and significant at the 1% level, while AI disclosure also remains positive and significant at the 1% level. The interaction term between ADVERM and centered AI disclosure is negative and significant at the 5% level. This result is consistent with the main regression and indicates that AI disclosure weakens, rather than strengthens, the positive association between advanced ERM practices and firm performance.

Among the control variables, leverage remains negative and significant across both models, while innovation and firm age are not statistically significant. Overall, the CEM results support the robustness of the main findings after improving the comparability between firms with and without advanced ERM practices.

Table 9
CEM Robustness Test

	(1)	**(2)**
	ROE	**ROE**
ADVERM	0.068***	0.076***
	(2.89)	(3.10)
AI (centered)	0.002***	0.002***
	(3.04)	(2.92)
ADVERM × AI (centered)		-0.002**
		(-2.00)
LEV	-0.085***	-0.085***
	(-4.71)	(-4.73)
INNOV	16.564	15.973
	(1.33)	(1.31)
AGE	0.000	0.000
	(0.34)	(0.34)
Constant	0.124**	0.126**
	(2.16)	(2.20)
Year FE	Yes	Yes
Industry FE	Yes	Yes
F	4.059	4.024
Adjusted R-squared	0.162	0.163
N	1437	1437

Notes: This table reports the CEM robustness test results. The dependent variable is ROE. ADVERM represents the Advanced ERM indicator; AI represents artificial intelligence disclosure; LEV represents leverage; INNOV represents innovation; and AGE represents firm age. Model 1 examines the direct associations of ADVERM and AI disclosure with ROE, while Model 2 includes the interaction term between ADVERM and AI disclosure. The regressions

are estimated using the matched sample and CEM weights. Year and industry fixed effects are included as indicated. The t-statistics are reported in parentheses and are based on firm-level clustered standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Continuous variables are winsorized at the 1st and 99th percentiles.

Discussion

The regression results provide evidence that ERM is positively associated with firm performance. This finding is consistent with the view that ERM functions as an important governance mechanism that improves risk identification, internal control, accountability, and managerial decision-making. Firms with more advanced ERM practices may be better able to coordinate risk responses across business units, allocate resources more effectively, and reduce performance volatility. This result is consistent with prior studies showing that ERM contributes to firm performance and value creation (Anugerah et al., 2023; Chairani & Siregar, 2021; Farrell & Gallagher, 2019; Horvey & Odei-Mensah, 2024; Malik et al., 2020; Saeidi et al., 2021). From an agency theory perspective, the finding suggests that ERM can help reduce information asymmetry and improve managerial accountability, thereby supporting better financial outcomes.

The positive association between AI disclosure and ROE indicates that firms with greater AI-related disclosure tend to perform better. This finding suggests that AI disclosure may reflect firms' digital orientation, technological awareness, and strategic attention to innovation. Although AI disclosure does not necessarily represent the maturity of AI implementation, it may signal that firms are more attentive to technology-related transformation and more responsive to changes in the business environment. This result is aligned with prior research suggesting that AI-related capabilities, AI disclosure, and digital transformation can support firm performance through improved decision-making, disclosure quality, innovation, operational efficiency, and strategic responsiveness (Alzeghoul & Alsharari, 2025; Marioni et al., 2024; Olan et al., 2022; Shiyyab et al., 2023; Sullivan & Wamba, 2024; Yang & Zhou, 2025).

However, the negative and significant interaction between ERM and AI disclosure indicates that AI disclosure does not strengthen the positive relationship between ERM and firm performance. Instead, AI disclosure attenuates the ERM-performance relationship. This finding does not support H3, which predicted that AI disclosure would strengthen the positive association between ERM and firm performance. One possible explanation is that AI-related disclosure may reflect early-stage digital orientation or strategic communication rather than fully developed AI capabilities. Although digital intelligence transformation can enhance the effectiveness of enterprise risk management, the value created by AI depends on supporting organizational conditions, including data assets, managerial capability, and organizational integration (Shi et al., 2025; Wang & Yang, 2026). When firms disclose AI-related initiatives without sufficient data governance, technological infrastructure, system compatibility, employee capability, and managerial readiness, the integration of digital initiatives with ERM may create complexity and coordination challenges. As a result, AI disclosure may reduce the incremental performance benefits of ERM rather than amplify them.

This finding provides an important boundary condition in the relationship between ERM and firm performance. While ERM and AI disclosure are independently associated with better performance, their interaction suggests that digital orientation alone is not sufficient to

enhance the value of risk management. Firms need to ensure that AI-related initiatives are strategically aligned with ERM systems and supported by adequate organizational capabilities. From a resource-based view perspective, ERM and AI-related orientation can create value only when they are effectively integrated with firm resources, systems, and managerial capabilities (Barney, 1991; Olan et al., 2022; Shi et al., 2025; Sullivan & Wamba, 2024). Therefore, the findings highlight that AI disclosure may be beneficial as a performance-related factor, but it does not automatically complement ERM unless firms have the readiness to integrate digital transformation with risk governance.

The robustness tests using GLS and CEM provide additional support for the stability of the main findings. The GLS results show that the associations remain consistent under an alternative estimation approach, while the CEM results indicate that the findings persist after reducing covariate imbalance between firms with and without advanced ERM practices. These results strengthen the conclusion that ERM and AI disclosure are independently associated with stronger firm performance, while their interaction remains negative and significant. Thus, the robustness evidence suggests that the moderating role of AI disclosure is not sensitive to alternative estimation methods or matched sample analysis.

Conclusion

This study examines the relationship between ERM, AI disclosure, and firm performance among Indonesian non-financial listed firms. Using 2,355 firm-year observations from 471 companies listed on the Indonesia Stock Exchange during 2019-2023, this study provides evidence that ERM is positively associated with ROE. This finding suggests that firms with more advanced ERM practices tend to achieve stronger financial performance, supporting the view that ERM contributes to value creation through improved risk governance, internal control, and managerial decision-making (Chairani & Siregar, 2021; Saeidi et al., 2021).

The study also finds that AI disclosure is positively associated with ROE. This indicates that firms with greater AI-related disclosure tend to perform better, possibly because such disclosure reflects digital orientation, technological awareness, and strategic attention to innovation. This finding is consistent with prior studies suggesting that AI-related disclosure, AI-related capabilities, and digital transformation can support firm performance through improved decision-making, disclosure quality, innovation, operational efficiency, and strategic responsiveness (Alzeghoul & Alsharari, 2025; Olan et al., 2022; Shiyyab et al., 2023; Sullivan & Wamba, 2024; Yang & Zhou, 2025).

However, the interaction between ERM and AI disclosure is negative and significant. This indicates that AI disclosure does not strengthen the positive relationship between ERM and firm performance. Instead, AI disclosure attenuates this relationship, suggesting that digital orientation may not automatically complement risk management practices. One possible explanation is that AI-related disclosure may reflect early-stage digital transformation or strategic communication rather than mature technological capability. Although digital intelligence transformation may enhance ERM effectiveness, the value created by AI-related initiatives depends on supporting conditions such as data assets, managerial capability, organizational integration, technological infrastructure, employee capability, and managerial readiness (Shi et al., 2025; Wang & Yang, 2026). Therefore, firms need to ensure that AI-

related initiatives are properly aligned with ERM before integrating them into risk management processes.

This study contributes to the ERM and digital disclosure literature by showing that AI disclosure serves not only as a performance-related factor but also as a contextual factor in the relationship between ERM and firm performance. The findings provide evidence from an emerging market context where ERM practices and AI-related disclosure are still developing unevenly across firms. For practitioners, the findings highlight the importance of aligning AI-related initiatives with risk management systems. Firms should avoid treating AI disclosure as merely symbolic communication and should instead strengthen the organizational capabilities needed to translate digital orientation into performance benefits.

This study has several limitations. First, this study measures AI disclosure using the frequency of AI-related terms in annual reports. Although this approach captures firms' disclosed AI-related digital orientation and technological awareness, it may not fully represent the actual implementation, quality, or maturity of AI systems. Second, the study focuses on Indonesian non-financial listed firms, which may limit the generalizability of the findings to other sectors or countries. Third, firm performance is measured using ROE, while other performance indicators may capture different aspects of corporate outcomes. Future studies may develop more refined AI disclosure indices, distinguish between symbolic AI disclosure and substantive AI adoption, use alternative performance indicators such as ROA or firm value, and compare firms across different industries and countries.

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