INTERNATIONAL JOURNAL OF ECONOMICS AND FINANCE STUDIES
Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314
Received: 11.07.2026 | **Accepted:** 20.08.2026 | **Published Online:** 30.09.2026

-RESEARCH ARTICLE-

GREEN BANKING AS A MODERATOR OF ICT INVESTMENT AND FIRM SIZE ON BANK FINANCIAL PERFORMANCE

Martinus Eli Naben

Universitas Merdeka Malang, Indonesia
ORCID: https://orcid.org/0009-0009-9687-3351
Email: stanis0304@yahoo.com

Grahita Chandarin

Universitas Merdeka Malang, Indonesia
ORCID: https://orcid.org/0000-0002-7024-1315
Email: grahitac@unmer.ac.id

Prihat Assih

Universitas Merdeka Malang, Indonesia
ORCID: https://orcid.org/0009-0004-8518-9160
Email: prihat.assih@unmer.ac.id

Aljuprianus Susar

Universitas Negeri Malang, Indonesia
ORCID: https://orcid.org/0000-0002-8886-4019
Email: fraterpoli@gmail.com

—Abstract—

Amid accelerating digital transformation and growing expectations for sustainable finance, banks face increasingly complex resource allocation decisions, particularly because substantial technological expenditure does not invariably generate corresponding improvements in profitability. Against this background, the present study investigates the moderating role of green banking disclosure in the relationships between Information and Communication Technology (ICT) investment, firm size and bank financial performance. The empirical analysis employs a balanced panel

Citation (APA): Naben, M. E., Chandarin, G., Assih, P., Susar, A. (2026). Green Banking as A Moderator of ICT Investment and Firm Size on Bank Financial Performance. *International Journal of Economics and Finance Studies*, 18(03), 323-351. doi: 10.34109/ijefs.2026180314

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

comprising 28 banks listed on the Indonesia Stock Exchange over the 2021–2024 period, yielding 112 bank-year observations. Moderated regression analysis is conducted within a fixed-effects panel framework, incorporating mean-centred variables and heteroskedasticity-robust standard errors. The findings demonstrate that, at the mean level of green banking disclosure, ICT investment exhibits no statistically significant association with Return on Assets (ROA), whereas firm size contributes positively and significantly to financial performance. Conversely, both interaction coefficients—ICT × green banking and firm size × green banking—are positive and statistically significant, indicating that higher green banking disclosure strengthens the relationships between these resources and bank profitability. Additional robustness assessments establish that the moderating influence on firm size remains comparatively stable across specifications, while the corresponding effect on ICT investment varies with the application of clustered standard errors and lagged specifications, warranting a cautious interpretation. Collectively, these findings provide empirical support for the Resource-Based View (RBV) by highlighting the complementary relationships between organisational resources and sustainability-related capabilities. The study further offers practical implications for banking executives and regulatory authorities seeking to integrate digital transformation strategies with broader sustainable finance objectives.

Keywords: Information and Communication Technology Investment; Firm Size; Green Banking Disclosure; Bank Financial Performance; Panel Data; Fixed Effects.

INTRODUCTION

The relationship between information and communication technology (ICT) and banking sector financial performance continues to attract considerable attention from policymakers, financial institutions, creditors, investors and academic researchers internationally (Nguyen, 2024). Technological advancements have fundamentally reshaped banking operations worldwide, facilitating innovative business models, greater operational efficiency and substantial changes in how financial institutions engage with customers. Despite these developments, scholarly consensus has yet to emerge regarding the sustained financial benefits associated with ICT adoption (Xu et al., 2025). Contemporary banking institutions operate under two increasingly important strategic imperatives: accelerating digital transformation and incorporating sustainability principles into their activities. Investment in ICT offers opportunities to streamline transaction processing, minimise operating expenditure, enhance the reliability of data management and extend financial service accessibility. Nevertheless, empirical investigations have produced divergent conclusions concerning its contribution to financial outcomes. Positive associations between ICT expenditure, profitability and operational efficiency have been documented in several studies (Ho & Mallick, 2010; Vuong et al., 2025 & Fang, 2025). Conversely, other investigations have identified negative relationships between digital transformation and Return on Assets

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

(ROA) (Anh & Van Nguyen, 2026 & Zn et al., 2025). This apparent disconnect between substantial technological investment and realised productivity or financial gains reflects the ICT productivity paradox (Brynjolfsson, 1993 & Noor, 2025).

Beyond technological investment, organisational scale represents another important factor influencing banking profitability. Larger financial institutions typically benefit from more extensive financing opportunities, stronger risk diversification mechanisms and greater financial capacity to undertake technological development (Adam et al., 2018; Amimakmur et al., 2024; Ngware et al., 2020). Such advantages, however, do not consistently translate into superior financial outcomes. Evidence of a negative association between institutional size and profitability suggests that competition increasingly centred on digital banking services may diminish the traditional economic advantages associated with organisational scale (Siahaan et al., 2020; Van Thuy, 2021). Alongside these technological and organisational considerations, banking institutions face growing obligations to support sustainable development.

Within Indonesia, POJK No. 51/POJK.03/2017 establishes regulatory requirements for financial services institutions to adopt sustainable finance principles and publish sustainability reports. Two related but conceptually distinct dimensions are particularly relevant to this investigation. Green banking encompasses the substantive integration of environmental considerations into institutional operations, financial products, lending activities and organisational policies (Akhter et al., 2021). In contrast, green banking disclosure (GBD) concerns the information communicated about these activities through annual reports and sustainability reporting documents (Handajani, 2019; Nurhana et al., 2024). Because secondary data do not permit direct observation of actual environmental practices, the present investigation operationalises GBD as a reported indicator of banks' sustainability commitments and capabilities. Accordingly, the disclosure measure reflects what institutions communicate to stakeholders rather than providing direct evidence of the effectiveness of their environmental initiatives.

Existing research similarly offers conflicting evidence concerning the financial implications of environmentally oriented banking practices. Although sustainability initiatives have been associated with improvements in institutional reputation and environmental outcomes (Bose et al., 2024; Tan et al., 2025), other empirical findings suggest that sustainability-related disclosure may correspond with reduced profitability (Buallay, 2021; Walzer et al., 2024). Considered alongside the inconsistent evidence surrounding technological expenditure and organisational size, these findings point towards the importance of contextual factors in determining financial outcomes. More specifically, the economic contribution of institutional resources may depend on the complementary capabilities through which those resources are utilised. The theoretical foundation of this investigation integrates the Resource-Based View (RBV) (Barney, 1991) with the Natural-Resource-Based View (Hart, 1995). Within this perspective, ICT investment and organisational size constitute strategic resources, whereas green

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

banking represents a complementary capability influencing the extent to which these resources generate financial returns. Previous empirical investigations have predominantly treated green banking as an independent determinant of organisational performance (Akhter et al., 2021; Siahaan et al., 2020; Walzer et al., 2024), while alternative studies have considered moderating mechanisms associated with institutional size or governance arrangements (Nurhana et al., 2024; Rahmamita & Kahar, 2024). Comparatively limited attention has been devoted to examining GBD as a simultaneous moderator of the relationships linking technological resources and organisational scale with profitability, particularly across Indonesian listed banks during the period following the implementation of POJK 51/2017.

Addressing this research gap, the present study pursues two objectives: (1) to determine how ICT investment and firm size relate to bank financial performance and (2) to establish whether GBD moderates these relationships. Its contributions extend across theoretical, methodological and practical dimensions. First, the proposed moderating relationships are grounded explicitly in the principle of resource–capability complementarity derived from the RBV framework. Second, the empirical approach evaluates interaction effects through within-bank variation using fixed-effects estimation, mean-centred explanatory variables, robust standard errors and multiple robustness assessments. Third, the resulting evidence provides regulatory authorities and banking executives with insights into the potential complementarities between digital transformation initiatives and sustainability-oriented strategies.

The remainder of the article is organised into six sections. Section 2 establishes the theoretical framework, synthesises the relevant literature and develops the research hypotheses. Section 3 describes the dataset, operationalisation of variables and econometric estimation procedures. Section 4 reports the empirical findings and associated robustness assessments. Section 5 interprets and discusses the results, while Section 6 concludes by outlining the principal findings, their implications and the study's limitations.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

THEORETICAL BASES

According to the RBV, the foundations of enduring competitive advantage lie in organisational resources characterised by value, rarity, resistance to imitation and effective organisational deployment (Barney, 1991). The capacity to organise and mobilise these resources is particularly important because their contribution to organisational performance depends on the capabilities through which they are coordinated, integrated and strategically employed (Teece, 1997). This interpretation is consistent with research examining the organisational value of information technology (IT), which emphasises that technological resources generate performance benefits when supported by complementary organisational assets, including operational

processes, employee competencies and strategic capabilities (Bharadwaj, 2000; Melville et al., 2004). From a formal perspective, complementarity exists when expanding one activity increases the marginal economic return associated with another (Milgrom & Roberts, 1995). Within an econometric framework, such a relationship is represented by a positive coefficient on the interaction between the relevant variables.

Extending this resource-oriented perspective, the Natural-Resource-Based View (NRBV) identifies environmentally related organisational capabilities as potential foundations of competitive advantage. These capabilities encompass pollution prevention, responsible product stewardship and strategic commitments to sustainable development (Hart, 1995). Within financial institutions, their practical expression takes the form of green banking initiatives, including environmentally responsible financial products, digital service delivery, efficient resource consumption, environmental awareness among customers and lending decisions that incorporate ecological risk considerations (Akhter et al., 2021; Handajani, 2019). Additional theoretical support emerges from agency and legitimacy perspectives, which emphasise the informational role of sustainability reporting. By improving transparency and mitigating information asymmetries between organisational management and relevant stakeholders (Jensen, 1976; Watts & Zimmerman, 1990), such disclosures may contribute to reduced financing costs and stronger customer confidence. Financial performance in the present investigation is operationalised through ROA, which captures the extent to which banking institutions generate earnings from the assets under their management (Ray, 2024 & Nasution et al., 2021). The selection of this indicator reflects its ability to assess the efficiency with which an institution employs its overall asset base, including technology-related assets. Furthermore, ROA is an established and widely applied measure in empirical investigations of banking sector financial performance (Harrison & Muiru, 2021).

ICT Investment and Bank Financial Performance

ICT comprises the technological infrastructure required for information processing, management and dissemination, encompassing hardware, software applications, communication networks, data storage systems and cybersecurity mechanisms (Mahboub, 2018; Saeed & Ahmed, 2023). Within banking institutions, these technologies facilitate more efficient operations by improving information accessibility, shortening processing times and reducing the costs associated with financial service delivery (Putri et al., 2024; Qwader et al., 2025). Empirical research has frequently demonstrated favourable relationships between technological adoption, operational efficiency and institutional profitability (Akinrinade, 2020; AL-Qudah, 2019; Ho & Mallick, 2010; Xiliang et al., 2023). However, the evidence remains inconsistent. While some investigations report statistically insignificant effects of technological investment on financial outcomes (Mahboub, 2018; Okeke, 2024), others identify adverse short-term relationships between ICT expenditure, digital transformation and ROA, primarily attributable to substantial

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

implementation expenditure and recurring maintenance requirements (Noor, 2025 & Angriani et al., 2025). Taken together, these contrasting findings suggest that the financial consequences of ICT investment are neither uniformly positive nor negative but may vary according to the organisational circumstances in which technological resources are deployed. Accordingly, the first hypothesis is developed without specifying the anticipated direction of the relationship.

H1: *Information and communication technology investment affects the financial performance of banks.*

Firm Size and Financial Performance

Organisational size, conventionally operationalised through total assets, serves as an indicator of the financial and human resources available to banking institutions (Zadeh, 2012). Greater institutional scale may confer competitive advantages through economies of scale, improved access to lower-cost financing and enhanced opportunities for risk diversification (Adam et al., 2018; Alfadhli & AlAli, 2021; Amimakmur et al., 2024; Ngware et al., 2020). Nevertheless, agency theory suggests that organisational expansion can introduce additional managerial challenges by increasing monitoring complexity and creating greater scope for conflicts between organisational stakeholders (Jensen, 1976). Consistent with this perspective, empirical evidence has also identified unfavourable relationships between bank size and financial performance (Nurhana et al., 2024; Van Thuy, 2021). These competing theoretical arguments and contradictory empirical findings indicate that the financial implications of organisational scale remain uncertain. Consequently, the second hypothesis is formulated as follows:

H2: *Firm size affects the financial performance of banks.*

Green Banking and Bank Financial Performance

The adoption of environmentally responsible banking practices and their associated disclosures may strengthen institutional reputation, reinforce investor confidence and improve operational cost efficiency (Ai'ni Rahma Dewi & Pamungkas, 2024; Lalon et al., 2025; Muganyi et al., 2021; Xiliang et al., 2023). Nevertheless, these potential advantages must be considered alongside the financial burdens arising from regulatory compliance requirements and initial implementation expenditure, which may adversely affect profitability over shorter periods (Buallay, 2021; Walzer et al., 2024; Weber, 2017). Given the conflicting expectations concerning the direction of the direct relationship between GBD and financial performance, together with the present study's primary emphasis on its moderating function, no separate hypothesis is advanced for this direct effect. Instead, GBD is incorporated as a control term within the estimation framework, as detailed in Section 3.

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

Green Banking Disclosure as a Moderator

The moderating mechanism proposed in this investigation is conceptually distinct from the direct relationship between green banking and profitability. Rather than establishing whether green banking independently improves ROA, the analysis considers whether differences in green banking engagement influence the strength of the relationships linking ICT investment and organisational size to ROA.

ICT investment × green banking. Digital infrastructure underpins numerous green banking initiatives, including electronic banking services, electronic billing, paperless administrative procedures, online customer support and digitally managed complaint resolution systems (Table 3). Banks possessing well-developed green banking capabilities are more likely to have restructured their operational processes to integrate technological resources effectively. Under such conditions, ICT expenditure extends beyond the accumulation of technological costs by facilitating the substitution of resource-intensive physical operations, including energy consumption, paper-based procedures and extensive office networks, while simultaneously supporting the provision of value-added financial services. Consistent with the principle of resource complementarity (Melville et al., 2004; Milgrom & Roberts, 1995), this operational integration increases the marginal financial returns associated with ICT investment. By contrast, institutions exhibiting limited green banking capabilities may experience technological expenditure primarily as an additional financial burden, reflecting the mechanisms underlying the ICT productivity paradox. Empirical support for the mutually reinforcing contributions of ICT and green finance to sustainable financial outcomes is provided by Muganyi et al. (2021) and Xiliang et al. (2023). Accordingly:

H3: *Green banking disclosure moderates (strengthens) the influence of information and communication technology investment on bank financial performance.*

Firm size × green banking. Implementing green banking initiatives requires considerable fixed expenditure associated with environmental risk management frameworks, sustainability reporting mechanisms, employee training and energy-efficient infrastructure. Larger banking institutions are better positioned to distribute these costs across a more extensive asset base, thereby reducing their relative financial burden. Moreover, greater institutional visibility may strengthen the legitimacy and reputational advantages arising from environmentally responsible banking activities (Nurhana et al., 2024; Platonova et al., 2018). From this perspective, organisational scale enables green banking initiatives to evolve from an additional cost obligation into a mechanism of competitive differentiation. Simultaneously, green banking capabilities facilitate the strategic allocation of scale-related resources towards activities recognised and valued by financial markets and regulatory authorities. Evidence that sustainability initiatives may impose additional operational burdens (Buallay, 2021; Weber, 2017) does not contradict this complementary relationship. Rather, such findings reinforce the

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

argument that these costs may exert disproportionately greater financial pressure on smaller institutions with more limited capacity to absorb fixed expenditure. Accordingly:

H4: *Green banking disclosure strengthens the influence of firm size on bank financial performance.*

Research Gap

The preceding literature synthesis identifies three principal gaps warranting further investigation. First, empirical research on green banking within the Indonesian banking sector has predominantly concentrated on its direct association with profitability (Siahaan et al., 2020; Walzer et al., 2024). Where moderating relationships have been considered, analyses have generally focused on the influence of green banking on financial ratio–performance relationships within particular institutional categories, including Sharia commercial banks (Ai'ni Rahma Dewi & Pamungkas, 2024).

Second, research incorporating technological factors has primarily conceptualised IT innovation as a moderator of the relationship between organisational size and financial performance (Amimakmur et al., 2024), leaving comparatively unexplored the extent to which sustainability-related capabilities influence the financial returns generated by technological investment. Third, a substantial proportion of earlier investigations have relied on pooled regression or random-effects specifications without mean-centring explanatory variables, thereby complicating the interpretation of main-effect coefficients in models incorporating interaction terms. To address these limitations, the present study jointly investigates two moderating relationships across the population of listed banking institutions, employing fixed-effects estimation to identify within-bank relationships, mean-centred variables to facilitate coefficient interpretation and robustness assessments to evaluate the consistency of the empirical findings.

RESEARCH METHODOLOGY DATA AND SAMPLES

The empirical investigation adopts a panel data framework integrating cross-sectional observations of banking institutions with annual time-series data covering 2021–2024. The target population comprises 47 banks listed on the Indonesia Stock Exchange (IDX). This observation period was chosen to capture developments following the introduction of mandatory sustainability reporting requirements for all commercial banks under POJK 51/2017, alongside the rapid expansion of digital transformation initiatives across the banking sector. The procedures and criteria applied in determining the final sample are detailed in Table 1.

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

Table 1: Sample Selection Process

Stage	Number of Banks	Bank-Year Observations
Bank population in Indonesia (BPS, 2023)	105	–
Banks listed on the IDX	47	–
Less: banks that did not consistently publish annual and sustainability reports for the 2021–2024 period	(17)	–
Banks meeting the criteria	30	120
Less: banks identified as outliers (1.5 × IQR criterion)	(2)	(8)
Final sample	28	–
Expected bank-year observations (28 × 4)	–	112
Actual observations used in the main regression	–	112
Observations for robustness test with one-year lagged ICT (28 × 3)	–	84

Source: Statistics Indonesia (2023), IDX Channel, and bank annual reports (processed data). The two banks excluded as outliers are PT Bank Mestika Dharma Tbk (BBMD) and PT Bank Multiarta Sentosa Tbk (MASB). The full re-estimation involving 30 banks is presented in the stress test (Table 8).

Following the sample selection procedure, the final dataset comprises 28 banking institutions observed over four years, yielding 112 bank-year observations. Complete data availability across all institutions and observation periods produces a balanced panel without missing values. To assess whether the exclusion of two outlier banks materially influenced the empirical conclusions, the principal regression model was additionally estimated using the expanded sample of 30 banks, comprising 120 observations. Information concerning ICT investment and GBD was extracted manually from annual and sustainability reports available through the respective banks' official websites. Financial information, specifically total assets and net profit, was retrieved from the Osiris database (Nurhana et al., 2024).

Variable Measurement

Table 2 provides the operational definitions and measurement procedures adopted for the study variables. All variables measured as ratios are reported in percentage terms, whereas organisational scale is operationalised using the natural logarithm of total assets.

Table 2: Operational Definition of Variables

Variable	Symbol	Measurement	References
Bank financial performance	ROA	Net profit / total assets × 100%	(Surya et al., 2021); Ray (2024)
ICT investment	ICT	Total ICT costs / total assets × 100%	Okeke (2024); (Riswanto et al., 2024)
Firm size	FS	Ln (total assets)	Adam et al. (2018)
Green banking disclosure	GBD	Number of disclosed indicators / 21 indicators (0–1)	Akhter et al. (2021); Handajani (2019); Nurhana et al. (2024)

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

To maintain terminological clarity and consistency throughout the analysis, the following abbreviations are applied uniformly: ROA denotes bank financial performance, ICT represents technological investment, FS refers to firm size, and GBD identifies the green banking disclosure index.

The mathematical expressions employed to operationalise and calculate the respective study variables are presented as follows:

$$ROA_{it} = \frac{\text{Net profit Total assets}}{\text{Total assets}} \times 100\% \quad (1)$$

$$ICT_{it} = \frac{\text{Total ICT costs}}{\text{Total assets}} \times 100\% \quad (2)$$

$$FS_{it} = \text{Ln(Total assets)} \quad (3)$$

$$GBDi = \frac{\sum 21\ dij=1}{\text{Total assets}} \times 100\% \quad (4)$$

With dij = 1 if bank i discloses indicator j and 0 if not, and N = 21 is the expected number of indicators. GBD indicators are presented in Table 3.

Table 3: Green Banking Disclosure (GBD) Index Indicators

Dimension	Code	Indicator
Green product	GBDI-1	Digital banking to reduce emissions
	GBDI-2	E-billing
	GBDI-3	Use of information technology in introducing banking products
	GBDI-4	Transparency regarding features, fees, benefits, and risks of e-banking products
	GBDI-5	Financing for eco-friendly/renewable energy projects (green projects)
	GBDI-6	Environmental Impact Assessment (AMDAL) documentation requirements for credit granting (green financing)
	GBDI-7	Green office/green building
Green operational	GBDI-8	Efficiency in resource consumption (electricity, water, fuel)
	GBDI-9	Reduction in paper usage (paperless approach)
	GBDI-10	Waste management, utilization, and recycling
	GBDI-11	Provision of energy-saving infrastructure
	GBDI-12	Initiation of greenhouse gas emission mitigation
Green customer	GBDI-13	Educating customers on conducting transactions online (via internet, phone, and SMS banking)
Dimension	**Code**	**Indicator**
	GBDI-14	Leveraging information technology for online customer services
	GBDI-15	Responsive handling of customer complaints via digital banking
	GBDI-16	Company directives and regulations to minimize operational

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

		environmental impact
Green policy	GBDI-17	Policy on the distribution of community development and partnership funds (green partnership)
	GBDI-18	Consideration of environmental aspects in strategic planning and business decisions
	GBDI-19	Commitment to and policies for eco-friendly banking
	GBDI-20	Policies on environmental conservation training and education for employees and the community
	GBDI-21	Bank initiatives to involve employees in green movements

Source: adapted from Akhter et al. (2021) and Handajani (2019).

Index Validity and Content Analysis Procedures

The selection of the 21 indicators was guided by three principal considerations. First, their applicability and validity have been established in previous investigations of green banking practices conducted in Bangladesh and Indonesia (Akhter et al., 2021; Handajani, 2019; Nurhana et al., 2024). Second, the indicators collectively represent four dimensions corresponding to the sustainable finance framework established under POJK 51/2017, encompassing financial products, institutional operations, customer-related activities and organisational policies. Third, each indicator can be assessed using publicly accessible documentation, thereby supporting methodological transparency and research replicability. An equally weighted, or unweighted, approach was adopted to construct the composite index because no sufficiently established theoretical justification exists for differentiating the relative importance of individual indicators. This measurement strategy is also consistent with established applications of dichotomous disclosure indices (Akhter et al., 2021).

The measurement process involved systematic content analysis of annual reports and sustainability reports published by each banking institution. Before commencing the assessment, a standardised coding protocol was developed to specify the operational definition of every indicator and provide illustrative examples of qualifying disclosures. Binary scores were subsequently assigned, with a value of 1 recorded exclusively when the relevant documentation explicitly identified a policy, programme or activity satisfying the corresponding indicator definition. Two coders independently evaluated the reporting materials to strengthen the reliability of the assessment procedure. Inter-coder consistency was examined using Cohen's kappa, yielding $\kappa = 0.85$, which indicates a very high degree of agreement. Any differences between the initial coding assessments were reconciled through discussion and further examination of the original reporting documents against the established coding protocol. Across the resulting dataset, individual banks exhibited identical GBD scores in every observation year from 2021 to 2024. Consequently, GBD constitutes a time-invariant variable at the institutional level, a characteristic whose implications for econometric estimation are addressed in the model specification.

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

Importantly, the constructed GBD index captures the extent of reported environmental commitments and activities rather than their verified implementation or operational effectiveness. Assigning an indicator, a value of 1 therefore establishes that the relevant bank disclosed a qualifying policy, programme or initiative, without independently confirming the extent or success of its practical execution. Accordingly, the analysis consistently interprets the resulting measure as GBD or the green banking index, rather than as direct evidence of substantive environmental performance. The limitations associated with this disclosure-based measurement approach are examined further in Section 6.

Model Specifications and Estimation Strategies

Figure 1 illustrates the conceptual framework underpinning the investigation. A sequential estimation strategy was adopted to differentiate the independent relationships of the explanatory variables with financial performance from their conditional relationships arising through moderation. Model 1 incorporates the main effects of ICT investment and FS, while Model 2, designated as the principal empirical specification, extends this framework by introducing two interaction terms:

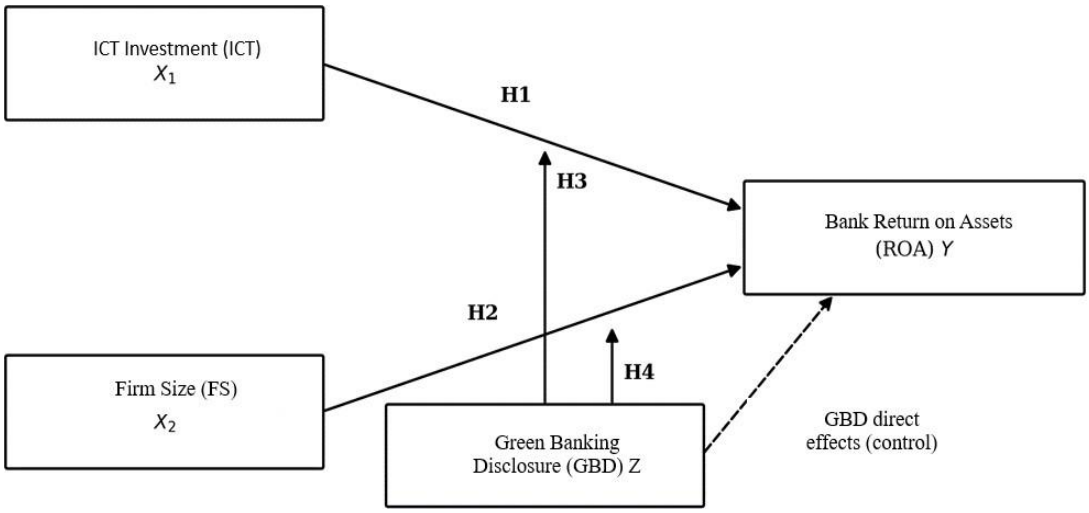


Figure 1: Research Framework

$$ROA_{it} = \alpha_i + \beta_1 ICT^c + \beta_2 FS^c + \varepsilon_{it} \quad (5)$$

$$ROA_{it} = \alpha_i + \beta_1 ICT^c + \beta_2 FS^c + \beta_3 (ICT^c \times GBD^c) + \beta_4 (FS^c \times GBD^c) + \varepsilon_{it} \quad (6)$$

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

In the specified regression framework, αi denotes the bank-specific fixed effect, whereas εit represents the stochastic error term. The superscript c identifies mean-centred variables, calculated as ICTc = ICT − 1.355, FSc = FS − 18.482 and GBDc = GBD − 0.884. Consistent with the procedure established by (Aiken & West 1991), mean-centring was undertaken before generating the interaction terms. Without this transformation, β1 and β2 would represent the respective relationships of ICT and FS with financial performance when GBD = 0, a reference point outside the observed distribution, given that the minimum GBD value is 0.571. Following mean-centring, these coefficients capture the relationships between ICT, FS and financial performance at the sample mean of GBD. Meanwhile, β3 and β4 quantify the changes in the corresponding relationships associated with a one-unit increase in GBD. Although mean-centring leaves the interaction coefficients and overall model fit unchanged, it facilitates substantively meaningful interpretation of the main effects and alleviates non-essential multicollinearity.

Main Effect of GBD

Standard moderation frameworks generally incorporate the independent contribution of the moderating variable alongside the relevant interaction terms. Within the present fixed-effects specification, GBD is accounted for through the institutional fixed effects, although its individual coefficient cannot be separately identified. This limitation arises because GBD exhibits no within-bank variation over the observation period and is therefore perfectly absorbed by αi (Wooldridge, 2010). Its absence as an independently estimated coefficient consequently reflects the identification properties of the model rather than an arbitrary exclusion. To obtain an explicit estimate of the GBD coefficient, the analysis additionally introduces Model 3, based on the correlated random effects (CRE) framework developed through the Mundlak (1978) approach. This specification extends random-effects estimation by incorporating GBDc alongside bank-level averages of every time-varying explanatory variable. Under this formulation, the estimated coefficients associated with time-varying regressors coincide with their fixed-effects counterparts, while coefficients for time-invariant characteristics, including GBD, can also be estimated.

Model Selection

The appropriate panel estimation framework is established through a sequence of specification tests comparing the common effect model (CEM), fixed effect model (FEM) and random effect model (REM). Specifically, the Chow test, Breusch–Pagan Lagrange Multiplier (LM) test and Hausman test are employed to evaluate the suitability of alternative panel structures. The outcomes of these diagnostic procedures inform the selection of the estimator used for the principal empirical analysis.

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

Inference

Evidence of heteroskedasticity identified through the Glejser test, as reported in Section 4, necessitates an estimation strategy that accommodates non-constant error variance. Accordingly, the primary statistical inference employs White's heteroskedasticity-robust standard errors, implemented through the White diagonal correction (White, 1980). Model performance is evaluated using R^2, adjusted R^2, within-R^2, the F-statistic and the robust Wald statistic. All estimations were initially conducted in EViews 13, with the results independently cross-validated using the statsmodels package in Python.

Endogeneity and Robustness Test

The inclusion of bank-specific fixed effects accounts for unobserved institutional characteristics that remain constant over time, including ownership structures, established business models and organisational culture. Nevertheless, this approach cannot fully address potential endogeneity arising from reverse causation. For example, banks exhibiting stronger profitability may possess greater financial capacity to undertake ICT investment, rather than technological expenditure necessarily producing higher profitability. The estimated coefficients are therefore interpreted as conditional statistical associations rather than evidence of causal effects. To examine the stability of the principal findings, four supplementary specifications are estimated: (1) a model employing bank-level clustered standard errors robust to heteroskedasticity and within-bank autocorrelation; (2) a two-way fixed-effects specification incorporating both bank and year effects; (3) a model introducing ICT investment lagged by one period (ICT_{t-1}) to account for potentially delayed technological returns and reduce simultaneity concerns; and (4) an expanded-sample estimation covering all 30 banks, including the previously excluded outliers.

RESEARCH RESULT

Descriptive Statistics and Correlation

The descriptive statistics reported in Table 4 reveal considerable variation in financial performance across the sampled banking institutions. Mean ROA stands at 1.337%, accompanied by a standard deviation of 1.345%, indicating substantial dispersion in profitability, as the variability is almost equivalent to the average return. At the lower end of the distribution, Bank Mayapada (MAYA) recorded an ROA of 0.020% in 2022, whereas BTPN Syariah (BTPS) achieved the highest observed value of 8.410% during the same year. Technological expenditure similarly exhibits notable differences across institutions, with ICT investment averaging 1.355% of total assets. The minimum value of 0.520% was observed for Bank INA (BINA) in 2021, while Bank Jago (ARTO) registered the maximum of 4.090% in 2022. This variation illustrates differences in the intensity of technological investment between conventional banking institutions and digitally oriented banks.

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

Regarding organisational scale, the mean FS value is 18.482, measured as the natural logarithm of total assets. Bank Oke Indonesia (DNAR) exhibited the smallest recorded value of 15.860 in 2021, whereas Bank Mandiri (BMRI) attained the highest value of 21.610 in 2024. The GBD index averages 0.884, corresponding to approximately 18.6 disclosed indicators out of the 21 assessed. Bank Bumi Arta (BNBA) registered the lowest disclosure score of 0.571, while nine institutions achieved the maximum observed score of 0.952, including OCBC NISP (NISP), Bank Sinarmas (BSIM) and Bank bjb (BJBR). Preliminary diagnostic assessments further indicate that pairwise correlations among the explanatory variables remain below 0.80, with all variance inflation factor (VIF) values falling below 10. These results suggest that severe multicollinearity is unlikely to compromise the subsequent regression analysis.

Table 4: Descriptive Statistics, Correlations, and VIF (N = 112 Bank-Year Observations; 28 Banks)

Variable	Average	Std Dev	Min.	Max.	ICT	FS	GBD	VIF
ROA (%)	1,337	1,345	0,020	8,410				
ICT (%)	1,355	0,684	0,520	4,090	1,000			1,294
FS (Ln asset)	18,482	1,642	15,860	21,610	−0,226	1,000		1,125
GBD (0–1)	0,884	0,094	0,571	0,952	−0,470	0,322	1,000	1,370

Note: ICT = ICT Investment; FS = Firm Size; GBD = Green Banking Disclosure Index. Pearson correlations among independent and moderator variables. VIF values were calculated from a regression including ICT, FS, and GBD. In the model with the centred interaction term, the highest VIF value was 6.797 (FS × GBD), remaining below the threshold of 10.

Selection of Panel Data Models

Table 5 summarises the diagnostic tests undertaken to determine the appropriate panel estimation framework. All specification tests are conducted using Model 2 and the sample comprising 28 banking institutions.

Table 5: Model Selection Test Summary

Test	Comparison	Statistic	df	Prob.	Decision
Chow (Cross-section F)	CEM vs FEM	16,475	(27; 80)	< 0,001	FEM
Chow (Cross-section χ^2)	CEM vs FEM	210,678	27	< 0,001	FEM
LM Breusch–Pagan (cross-section)	CEM vs REM	80,663	1	< 0,001	REM
Hausman (cross-section random)	REM vs FEM	25,156	4	< 0,001	FEM
Mundlak (Wald, bank average)	REM vs FEM	22,815	4	< 0,001	FEM

Note: CEM = Common Effect Model; FEM = Fixed Effect Model; REM = Random Effect m=Model. The time component of the Breusch–Pagan LM test was not significant (1.697; p = 0.193).

Both the Chow and LM tests provide sufficient statistical evidence to reject the CEM, confirming the existence of unobserved heterogeneity across banking institutions. Subsequent evaluation using the Hausman test also leads to the rejection of the REM, indicating that bank-specific unobserved effects are correlated with the explanatory

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

variables and consequently undermine the consistency of conventional random-effects estimates. The Mundlak test corroborates this finding, providing further justification for adopting the FEM as the preferred estimation framework. Accordingly, all principal hypothesis tests are conducted using the FEM. The REM is retained exclusively through the CRE specification (Model 3), which is constructed to reproduce the FEM coefficients for time-varying explanatory variables while permitting separate estimation of the main effect associated with GBD.

Diagnostic Test

The Glejser procedure was applied to the FEM residuals by estimating a regression of their absolute values against the complete set of explanatory variables. The resulting F-statistic of 14.229 ($p < 0.001$), together with the statistically significant ICT × GBD interaction term, provides evidence of heteroskedasticity in the regression disturbances.

Moderated Regression Estimation Results

Table 6: Panel Data Regression Estimation Results (Dependent Variable: ROA)

Variable	Model 1 FEM Main Effects	Moderated FEM Model 2 (Main)	Model 3 CRE (Mundlak)
Constant	1.337	0.981	1.240***
			(0.182)
ICT^c	−0.351	−0.043	−0.043
	(0.270)	(0.213)	(0.228)
FS^c	0.611*	1.002***	1.002***
	(0.350)	(0.313)	(0.376)
GBD^c	absorbed α_i	absorbed α_i	−7.097
			(4.797)
ICT^c × GBD^c		5.670**	5.670*
		(2.641)	(3.013)
FS^c × GBD^c		10.631**	10.631
		(4.596)	(7.612)
Bank fixed effects	Ya	Ya	Bank average (Mundlak)
N (observation) / bank	112 / 28	112 / 28	112 / 28
R^2	0.900	0.915	–
Adjusted R^2	0.865	0.882	–
Variable	**Model 1 FEM Main Effects**	**Moderated FEM Model 2 (Main)**	**Model 3 CRE (Mundlak)**
R^2 *within*	0.050	0.193	–
Statistik F (*p*)	25.493 (< 0.001)	27.854 (< 0.001)	–
Wald F robust (*p*)	3.691 (0.029)	5.060 (0.001)	–
F changes from Model 1 (*p*)	–	7.099 (0.001)	–

Note: Figures in parentheses are White heteroskedasticity-robust standard errors. ***, **, and * indicate significance at the 1%, 5%, and 10% levels (two-tailed test, df = 80 for Model 2). The superscript c denotes centered variables. In the FEM, the constant represents the mean of the bank fixed effects. GBD

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

is time-invariant; thus, its main effect is absorbed into the bank fixed effects in Models 1 and 2. Model 3 estimates it using the Mundlak approach by including bank-level means of ICTc, FSc, and the two interaction terms (coefficients not shown). The FEM R^2 and adjusted R^2 correspond to the LSDV model R^2 (including bank fixed effects), while the "within" R^2 measures the within-bank variation in ROA explained by the regressors. Detailed t-statistics and p-values are presented in the text.

Consequently, the primary statistical inference is based on White's heteroskedasticity-robust standard errors. As an additional assessment of the potential influence of within-bank serial correlation, the regression results were re-evaluated using standard errors clustered at the institutional level, as reported in Table 8.

$$ROA_{it} = \alpha_i - 0{,}043ICT^c_{it} + 1{,}002FS^c_{it} + 5{,}670(ICT^c_{it} \times GBD^c_{it}) + 10{,}631(FS^c_{it} \times GBD^c_i) \quad (7)$$

Model Explanatory Power

Model 2 yields an R^2 of 0.915 and an adjusted R^2 of 0.882, indicating a high overall proportion of explained variation. However, these values largely reflect the contribution of bank-specific fixed effects, which account for persistent differences in profitability across institutions, rather than the predictive accuracy of the explanatory variables. Consequently, within-R^2 provides a more informative assessment of the model's explanatory contribution. The estimated within-R^2 of 0.193 indicates that ICT investment, FS and their respective interaction terms account for 19.3% of the annual variation in ROA within individual banks. Introducing the moderating relationships increases within-R^2 from 0.050 in Model 1 to 0.193 in Model 2. This improvement is statistically significant ($F = 7.099$; $p = 0.001$), demonstrating that incorporating the interaction terms substantially strengthens the model's explanatory capacity.

Testing H1

The estimated coefficient for ICTc in Model 2 is −0.043 ($t = -0.200$; $p = 0.842$). Because the explanatory variables are mean-centred, this estimate represents the relationship between ICT investment and ROA when GBD is held at its sample average. The coefficient is negligible in magnitude and statistically insignificant, indicating insufficient evidence of a relationship under this condition. A comparable result emerges from Model 1, which excludes the moderating terms, where the ICT coefficient is −0.351 ($p = 0.197$). Accordingly, H1 is not supported, as the empirical findings do not establish a statistically significant general association between ICT investment and banking profitability.

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

Testing H2

Model 2 produces a positive and statistically significant coefficient for FSc of 1.002 (t = 3.198; p = 0.002). At the average GBD level, a one-unit increase in a bank's natural logarithm (Ln) of total assets is associated with an approximately 1.00 percentage point improvement in ROA. This finding provides empirical support for H2. Although Model 1 also identifies a positive relationship between FS and financial performance, its coefficient of 0.611 (p = 0.085) achieves statistical significance only at the 10% threshold. The stronger association observed in Model 2 suggests that accounting for differences in GBD provides a clearer representation of the relationship between organisational scale and profitability.

Testing H3 and H4

Both moderating relationships exhibit positive and statistically significant coefficients in the principal specification. Specifically, the estimated coefficient for ICTc × GBDc is 5.670 (t = 2.147; p = 0.035), whereas FSc × GBDc yields a coefficient of 10.631 (t = 2.313; p = 0.023). As both interaction terms satisfy the 5% significance criterion, H3 and H4 receive empirical support in Model 2. These estimates represent changes in the conditional slopes of the corresponding resource–performance relationships rather than independent effects on profitability. More precisely, an increase of 0.1 in GBD, approximately equivalent to disclosing two additional indicators, raises the estimated ICT–ROA slope by 0.567 and the FS–ROA slope by 1.063. Thus, higher disclosure levels are associated with stronger relationships between both resource dimensions and financial performance.

Main Effect of GBD

The CRE estimation presented in Model 3 identifies a negative but statistically insignificant coefficient for GBD (−7.097; p = 0.142). Consistent with the properties of the Mundlak estimator, the estimated coefficients for ICTc, FSc and both interaction terms are identical to those obtained under Model 2, although their standard errors are larger owing to random-effects weighting. These findings provide no statistically significant evidence of a direct relationship between GBD and profitability. Instead, the results suggest that its principal empirical relevance lies in moderating the associations between institutional resources and financial performance.

Simple Slope Analysis

To examine how the estimated relationships, vary across disclosure levels, the conditional effects of ICT and FS on ROA are illustrated in Figure 2 and summarised in Table 7. Three representative GBD values are considered: a low level corresponding to one standard deviation below the mean (0.790), the sample average (0.884) and a high level defined by the maximum observed value (0.952). The observed maximum is

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

used for the high-disclosure scenario because the conventional threshold of one standard deviation above the mean (0.979) exceeds the upper boundary of the sample distribution.

Table 7: Conditional Effect (Simple Slope) Based on Model 2

GBD Level	The Effect of ICT on ROA	*p*	Effect of FS on ROA	*p*
Low (0.790)	−0.578 (0.333)	0.087	−0.001 (0.542)	0.999
Average (0.884)	−0.043 (0.213)	0.842	1.002 (0.313)	0.002
High (0.952)	0.343 (0.274)	0.215	1.725 (0.436)	< 0.001

Note: Figures in parentheses are White robust standard errors.

The two moderating relationships exhibit distinct patterns. For FS, the estimated association with ROA is negligible among banks reporting low GBD, but becomes progressively stronger and positive at average and high disclosure levels. This pattern provides evidence of a genuine strengthening effect, whereby higher GBD reinforces the positive relationship between organisational scale and profitability. In contrast, the conditional relationship between ICT investment and ROA changes direction across disclosure levels. At low GBD, the estimated slope is negative (−0.578), although statistically significant only at the 10% threshold, whereas at high GBD, the coefficient becomes positive (0.343). Neither conditional estimate, however, reaches statistical significance at the 5% level. These findings suggest that GBD modifies the direction of the ICT–ROA association, with technological expenditure exhibiting a potentially unfavourable relationship with profitability among banks characterised by limited disclosure and a favourable relationship among institutions reporting higher disclosure levels. Nevertheless, the available statistical evidence remains insufficiently robust to establish that ICT investment generates significant improvements in ROA among banks with high GBD.

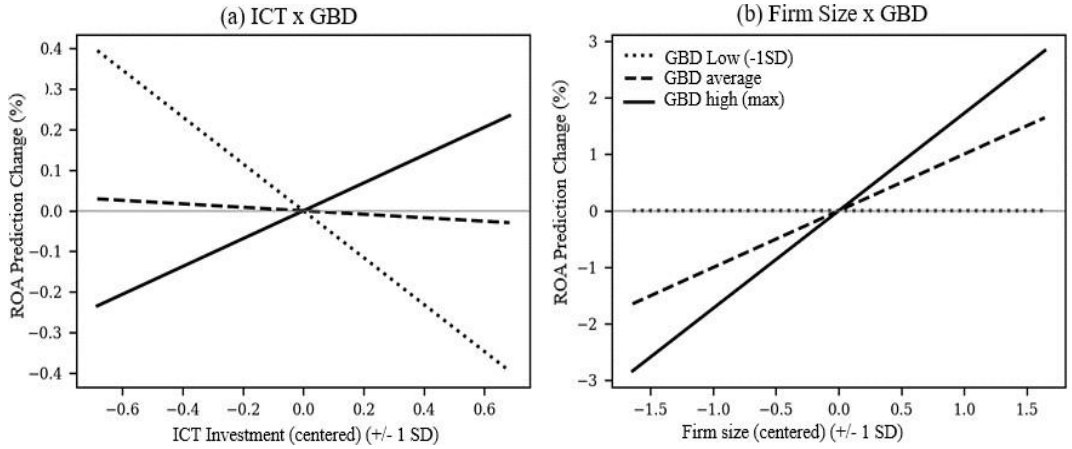


Figure 2: The Conditional Effects of ICT Investment and Firm Size on ROA at Various Levels of GBD

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

Robustness Test

The robustness assessments reveal important differences in the stability of the estimated moderating relationships. The interaction between GBD and FS remains statistically significant under bank-clustered standard errors and two-way fixed-effects estimation, while retaining significance at the 10% level when the full sample is considered. Similarly, the direct association between FS and ROA remains significant at a minimum threshold of 10% across all specifications except the two-way fixed-effects model. This exception is consistent with the possibility that changes in bank assets predominantly follow a shared temporal pattern, which is captured by the inclusion of year-specific fixed effects.

By comparison, the moderating influence of GBD on the ICT–ROA relationship exhibits considerably greater sensitivity to estimation choices. Although the interaction remains significant in the two-way fixed-effects specification and the expanded sample, its significance disappears when standard errors are clustered by bank ($p = 0.206$). Furthermore, introducing a one-year lag for ICT investment produces statistically insignificant interaction coefficients. Given the resulting reduction in sample size to 84 observations and the relatively brief observation period, these findings cannot establish whether the financial implications of ICT investment emerge with a temporal delay. Additional examination indicates that the estimated interaction effects are substantially influenced by institutions combining relatively high ICT expenditure with limited GBD, particularly BTPS and ARTO. Taken together, the results provide more consistent empirical support for GBD as a moderator of the FS–ROA relationship, whereas its moderating role in the ICT–ROA relationship should be regarded as preliminary and suggestive.

Table 8: Robustness Test (Dependent Variable: ROA)

Variable	(1) Bank-Clustered Standard Errors	(2) Two-Way Fixed Effects	(3) One-Year Lag in ICT	(4) Full Sample of 30 Banks
ICT^c (atau ICT^c_{t-1})	−0,043 (0,279)	−0,083 (0,212)	0,009 (0,552)	−0,156 (0,189)
FS^c	1,002** (0,400)	0,963 (0,709)	0,876* (0,502)	0,776** (0,324)
$ICT^c \times GBD^c$	5,670 (4,446)	6,255** (2,648)	4,359 (7,049)	5,431** (2,573)
$FS^c \times GBD^c$	10,631** (4,773)	10,682** (5,045)	−1,917 (6,962)	9,041* (4,693)
Variable	**(1) Bank-Clustered Standard Errors**	**(2) Two-Way Fixed Effects**	**(3) One-Year Lag in ICT**	**(4) Full Sample of 30 Banks**
N / bank	112 / 28	112 / 28	84 / 28	120 / 30
R^2 / *adjusted* R^2	0,915 / 0,882	0,920 / 0,885	0,904 / 0,847	0,914 / 0,881

Note: All models include bank fixed effects; model (2) also includes year fixed effects. Column (1) uses bank-clustered standard errors (White period); columns (2)–(4) use White robust standard errors. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

DISCUSSION

ICT Investment and the Conditional Productivity Paradox

The absence of a statistically significant average relationship between ICT investment and ROA is compatible with the ICT productivity paradox discussed in earlier research (Brynjolfsson, 1993; Hajli et al., 2015). Comparable empirical findings have also been documented by Mahboub (2018), Okeke (2024), and Noor (2025). Nevertheless, the conditional slope estimates suggest that the insignificant average association conceals meaningful differences across banks. Specifically, greater ICT expenditure tends to correspond with lower ROA among institutions exhibiting limited GBD, whereas the estimated relationship becomes positive among banks characterised by more extensive disclosure. Within the Indonesian banking context, this pattern suggests that the productivity paradox may depend partly on the organisational capabilities accompanying technological expenditure. Such heterogeneity offers a possible explanation for divergent conclusions in previous studies. Positive associations reported by Ho and Mallick (2010), Vuong et al. (2025), and (Zhuoyan, 2025), alongside negative relationships identified by Angriani et al., (2025) and Anh and Van Nguyen (2026), may reflect differences in the complementary capabilities represented within their respective banking samples.

From a theoretical standpoint, these findings are consistent with the proposition that the economic benefits of IT depend on its integration with complementary organisational resources (Bharadwaj, 2000; Melville et al., 2004). Several practices captured by the green banking indicators, including paperless transactions, electronic billing, online banking services, and digitally managed customer complaints, involve substituting technology-enabled procedures for conventional physical operations. Institutions reporting these activities may therefore have integrated technological expenditure with operational restructuring, potentially allowing efficiency improvements and reductions in operating costs to materialise. However, this interpretation requires qualification. The estimated ICT moderation effect becomes statistically insignificant under bank-clustered standard errors and lagged specifications, while its magnitude is influenced by digitally intensive and Sharia banking institutions. Consequently, the observed pattern should be interpreted as preliminary evidence of potential complementarity between technological and environmental capabilities rather than conclusive confirmation of such a relationship.

Firm Size and the Role of Strengthening Green Banking

The positive relationship identified between FS and ROA is consistent with the economic advantages associated with organisational scale and supports the empirical conclusions of Adam et al. (2018), Ngware et al. (2020), and Amimakmur et al. (2024). Importantly, because the analysis exploits changes occurring within individual banks, the findings suggest that improvements in profitability tend to accompany institutional expansion over time. They do not merely establish that larger institutions are inherently

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

more profitable than smaller competitors. Although this result contrasts with the evidence presented by Van Thuy (2021) and Siahaan et al. (2020), the observed moderating relationship offers a potential explanation. Among institutions characterised by low GBD, changes in FS exhibit an almost negligible association with ROA. Accordingly, analyses that disregard variation in disclosure-related capabilities may produce weak, insignificant, or potentially negative estimates of the relationship between organisational scale and profitability.

Among the relationships investigated, the moderating influence of GBD on the FS–ROA association demonstrates the greatest consistency across alternative specifications. This finding reinforces the proposition that larger institutions are better positioned to distribute the fixed expenditure associated with sustainability initiatives across their operations while potentially obtaining greater legitimacy-related advantages (Nurhana et al., 2024; Platonova et al., 2018). Within the NRBV framework (Hart, 1995), environmentally oriented capabilities provide a mechanism through which resources associated with organisational scale can be directed towards activities recognised as valuable by regulatory authorities, investors, and customers. The results further qualify the conclusions of Weber (2017 and {Buallay, 2021 #14), suggesting that sustainability-related expenditure may impose a comparatively greater financial burden on institutions without sufficient operational scale to accommodate such costs, rather than constituting a uniform disadvantage across the banking sector.

Green Banking Disclosure as a Capability, Not a Direct Driver of Profit

The statistically insignificant GBD coefficient obtained from Model 3 provides no empirical support for an independent association between disclosure practices and profitability. This outcome is consistent with the heterogeneous evidence reported in previous investigations (Lalon et al., 2025; Walzer et al., 2024). Rather than operating as an autonomous determinant of financial returns, GBD appears to derive its relevance from its interaction with existing institutional resources. This interpretation also offers a possible explanation for the inconsistent findings of studies that evaluate green banking exclusively through its direct relationship with financial performance.

CONCLUSIONS, IMPLICATIONS, AND LIMITATIONS

Using a fixed-effects estimation framework with mean-centred explanatory variables, this investigation evaluates whether GBD conditions the relationships linking ICT investment and FS to financial performance among 28 banks listed on the IDX during 2021–2024. Four principal conclusions emerge from the empirical analysis. First, ICT investment exhibits no statistically significant association with ROA when GBD is evaluated at its average level, providing insufficient support for H1. Second, the positive and statistically significant relationship between FS and ROA supports H2. Third, the primary model identifies a positive moderating relationship between GBD

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

and the ICT–ROA association, although its sensitivity to alternative standard-error estimators and lagged specifications necessitates a qualified interpretation of the support for H3. Fourth, GBD consistently reinforces the positive association between FS and ROA across most estimation approaches, providing comparatively robust evidence in favour of H4.

Theoretical Implications

By positioning environmentally oriented organisational capabilities as complementary to existing institutional resources, the findings broaden the relevance of the RBV and NRBV within banking research. Rather than suggesting that sustainability capabilities independently generate financial returns, the results emphasise their potential contribution to the effectiveness of other resources. They further suggest that the ICT productivity paradox may be better conceptualised as a context-dependent relationship shaped by differences in complementary organisational capabilities.

Practical Implications

The findings suggest that banking institutions should coordinate technological expenditure and green banking initiatives rather than administer them as unrelated investment priorities. Integrating digital transformation with environmental objectives, for example through the replacement of resource-intensive physical procedures with digital alternatives, may simultaneously reduce material consumption and operating expenditure. Smaller institutions should also recognise that the financial advantages associated with green banking may be more difficult to realise when operational scale is insufficient. Collaborative arrangements and shared technological or sustainability infrastructure therefore warrant consideration as potential alternatives. From a regulatory perspective, the results support further improvements in sustainable finance disclosure requirements, particularly measures that strengthen the correspondence between reported activities and their practical implementation while facilitating meaningful comparisons across banking institutions.

Limitations and Future Research

Several methodological and empirical constraints should be considered when interpreting these findings. First, the GBD index captures the extent of reported sustainability practices rather than their demonstrated operational effectiveness. Subsequent investigations could incorporate outcome-based measures, including the proportion of environmentally sustainable financing and the emissions intensity of banking operations. Second, GBD remains unchanged within each institution throughout the observation period, preventing its direct effect from being identified through conventional within-bank fixed-effects estimation. Although the CRE specification permits estimation of this time-invariant relationship, future studies

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

employing annually varying disclosure scores could examine how changes in GBD correspond with changes in financial performance.

Third, despite the capacity of bank fixed effects to account for persistent unobserved institutional characteristics, the possibility of reverse causality between profitability and ICT expenditure cannot be completely excluded. Extending the observation period would facilitate the application of dynamic panel estimation techniques, including the generalised method of moments (GMM), alongside more comprehensive lag structures. Fourth, the four-year panel and relatively small institutional sample restrict statistical power, particularly when bank-clustered standard errors are employed. Moreover, the interaction estimates exhibit sensitivity to a limited number of institutions with unusually pronounced characteristics, warranting caution regarding their generalisability. Fifth, reliance on ROA alone provides an incomplete representation of banking performance. Future analyses could incorporate return on equity (ROE), net interest margin (NIM), operating cost efficiency (BOPO), and market-based valuation measures such as Tobin's Q. Further comparative investigations across bank classifications, including KBMI categories, conventional and Sharia institutions, and digital and non-digital banks, could provide additional insight into the conditions under which technological expenditure and sustainability-related capabilities are associated with financial outcomes.

REFERENCES

Adam, M., Safitri, R., & Wahyudi, T. (2018). Effect of company size, liquidity and operational efficiency on bank profitability with problem credit risk as a moderating variable at commercial banks that are listed on the Indonesia Stock Exchange. *Jurnal Perspektif Pembiayaan dan Pembangunan Daerah*, *6*(3), 331 - 344. https://doi.org/10.22437/ppd.v6i3.5894

Ai'ni Rahma Dewi, S., & Pamungkas, I. D. (2024). Peran Green Banking sebagai pemoderasi pada Determinan Kinerja Keuangan Bank Umum Syariah Periode 2018-2022. *Al-Kharaj: Jurnal Ekonomi, Keuangan & Bisnis Syariah*, *6*(6), 3717 - 3733. https://doi.org/10.47467/alkharaj.v6i6.1175

Aiken, L. S., West, S. G., Park, N., & Sage, C. A. (1991). *Multiple Regression : Testing and Interpreting*. 167–168. https://www.sagepub.com/shop/buy-a-book/multiple-regression-1-3045

Akhter, I., Yasmin, S., & Faria, N. (2021). Green banking practices and its implication on financial performance of the commercial banks in Bangladesh. *Journal of Business Administration*, *42*(1), 1-23. https://iba-du.edu/upload_images/Vol.%2042_No.%201_Article_1.pdf

Akinrinade, A. A. (2020). Impact of ICT usage on financial performance of quoted manufacturing companies in Lagos State, Nigeria. *African Journal of*

Computing & ICT, 13(2), 28–42. https://afrjcict.net/wp-content/uploads/2020/07/Vol13No2Jun20pap3pagenumb.pdf

AL-Qudah, D. M. A. A. (2019). The Effect of Information Technology on Financial Performance of Jordanian Industrial Companies. *International Journal of Business and Social Science*, *10*(11), 113-121. https://doi.org/10.30845/ijbss.v10n11a14

Alfadhli, M., & AlAli, M. (2021). The Effect of Bank Size on Financial Performance: A Case Study on Kuwaiti Banks. *Journal of Insurance and Financial Management*, *4*(3), 11-15. https://www.researchgate.net/publication/352092630_The_Effect_of_Bank_Size_on_Financial_Performance_A_Case_Study_on_Kuwaiti_Banks

Amimakmur, S. A., Saifi, M., Damayanti, C. R., & Hutahayan, B. (2024). Assessing the moderating effect of IT innovation on the interplay among company size, financial performance, and company value. *Journal of Open Innovation: Technology, Market, and Complexity*, *10*(3), 100318. https://doi.org/10.1016/j.joitmc.2024.100318

Angriani Zn, S., Nursafitri, S., Juwita, T. P., & Irianto, E. D. O. (2025). Analysis of the influence of digital transformation on the financial performance of retail companies in Indonesia. *Journal of Artificial Intelligence and Digital Business (RIGGS), 4*(2), 6449–6454. https://doi.org/10.31004/riggs.v4i2.1640

Anh, N. T. L., & Van Nguyen, D. (2026). Balancing resources: Returns and the digital transformation of Vietnam's banking sector. *The Economics and Finance Letters*, *13*(1), 95-104. https://doi.org/10.18488/29.v13i1.4783

Barney, J. (1991). Firm Resources and Sustained Competitive Advantage. *Journal of Management*, *17*(1), 99-120. https://doi.org/10.1177/014920639101700108

Bharadwaj, A. S. (2000). A Resource-Based Perspective on Information Technology Capability and Firm Performance: An Empirical Investigation1. *Management Information Systems Quarterly*, *24*(1), 169-196. https://doi.org/10.2307/3250983

Bose, S., Khan, H. Z., & Bakshi, S. (2024). Determinants and consequences of sustainable development goals disclosure: International evidence. *Journal of Cleaner Production*, *434*, 140021. https://doi.org/10.1016/j.jclepro.2023.140021

Brynjolfsson, E. (1993). The productivity paradox of information technology. *Communications of the ACM*, *36*(12), 66-77. https://doi.org/10.1145/163298.163309

Buallay, A. M., Marri, M. Al, Nasrallah, N., Barone, E., & Zureigat, Q. (2021). Sustainability reporting in banking and financial services sector : a regional analysis. *Journal of Sustainable Finance & Investment*, 1-26. https://doi.org/10.1080/20430795.2021.1978919

Fang, Z. (2025). The influence of information and communication technology on firm financial performance. *SHS Web of Conferences, 215*, Article 01007. https://doi.org/10.1051/shsconf/202521501007

Hajli, M., Sims, J. M., & Ibragimov, V. (2015). Information technology (IT) productivity paradox in the 21st century. *International Journal of Productivity and Performance Management*, *64*(4), 457-478. https://doi.org/10.1108/IJPPM-12-2012-0129

Handajani, L., Husnan, L. H., & Rifai, A. (2019). Kajian Tentang Inisiasi Praktik Green Banking Pada Bank BUMN di Indonesia. *Jurnal Economia Review of Business and Economics*, *15*(1), 1-16. https://doi.org/10.21831/economia.v15i1.21954

Harrison, F. N., & Muiru, D. (2021). Effects of selected financial management practices on financial performance of commercial banks in Kenya. *International journal of finance*, *6*(1), 17-38. https://doi.org/10.47941/ijf.517

Hart, S. L. (1995). A Natural-Resource-Based View of the Firm. *The Academy of Management Review*, *20*(4), 986-1014. https://doi.org/10.2307/258963

Ho, S. J., & Mallick, S. K. (2010). The impact of information technology on the banking industry. *Journal of the Operational Research Society*, *61*(2), 211-221. https://doi.org/10.1057/jors.2008.128

Jensen, M. C., & Meckling, W. H. (1976). Theory of the firm: Managerial behavior, agency costs and ownership structure. *Journal of Financial Economics, 3*(4), 305–360. https://doi.org/10.1016/0304-405X(76)90026-X

Lalon, R. M., Faruk, M. O., & Amir, K. B. (2025). Investigating the impact of green banking initiatives on bank performance: empirical evidence from emerging economy. *Discover Sustainability*, *6*(1), 453. https://doi.org/10.1007/s43621-025-01279-6

Mahboub, R. M. (2018). The impact of information and communication technology investments on the performance of Lebanese banks. *European Research Studies Journal*, *21*(4), 435–458. https://doi.org/10.35808/ersj/1133

Melville, N., Kraemer, K., & Gurbaxani, V. (2004). Information Technology and Organizational Performance: An Integrative Model of IT Business Value1. *Management Information Systems Quarterly*, *28*(2), 283-322. https://doi.org/10.2307/25148636

Milgrom, P., & Roberts, J. (1995). Complementarities and fit strategy, structure, and organizational change in manufacturing. *Journal of Accounting and Economics*, *19*(2), 179-208. https://doi.org/10.1016/0165-4101(94)00382-F

Muganyi, T., Yan, L., & Sun, H.-p. (2021). Green finance, fintech and environmental protection: Evidence from China. *Environmental Science and Ecotechnology*, *7*, 100107. https://doi.org/10.1016/j.ese.2021.100107

Mundlak, Y. (1978). On the Pooling of Time Series and Cross Section Data. *Econometrica*, *46*(1), 69-85. https://doi.org/10.2307/1913646

Nasution, R. S. A. (2021). The influence of BOPO LDR, and leverage on financial performance (ROA) in banking companies listed on Bursa Effects Indonesia.

Enrichment: Journal of Management, 12(1), 442–445. https://doi.org/10.35335/enrichment.v12i1.240

Nguyen, T. H. (2024). The impact of capital structure on the performance of state-invested enterprises in Vietnam. *Cogent Economics & Finance*, *12*(1), 2399955. https://doi.org/10.1080/23322039.2024.2399955

Ngware, S. G., Olweny, T., & Muturi, W. (2020). Do bank size moderate relationship between banks' portfolio diversification and financial performance of commercial banks in Kenya. *SEISENSE Journal of Management*, *3*(2), 14-30. https://doi.org/10.33215/sjom.v3i2.261

Noor, M. M., Shanmugam, J. K., Kamarul, W., & Wan, H. (2025). The Effects of ICT Investment on Malaysian Technology-Based Firm Performance. *IX*. https://doi.org/10.47772/IJRISS

Nurhana, I. A., Triyono, T., & Sasongko, N. (2024). The Influence of Internal Factors, Bank Size, and Good Corporate Governance on the Performance of Commercial Banks Listed on the Indonesian Stock Exchange in 2021-2022. *International Journal of Economics, Business and Accounting Research (IJEBAR)*, *8*(1). https://doi.org/10.29040/ijebar.v8i1.12602

Okeke, C. (2024). Effect of Information and Communication Technology (ICT) on Financial Performance of Listed Consumer Goods Firms in Nigeria. *Economic Policy*, 1-33. https://ideas.repec.org/p/pra/mprapa/121293.html

Platonova, E., Asutay, M., Dixon, R., & Mohammad, S. (2018). The Impact of Corporate Social Responsibility Disclosure on Financial Performance: Evidence from the GCC Islamic Banking Sector. *Journal of Business Ethics*, *151*(2), 451-471. https://doi.org/10.1007/s10551-016-3229-0

Putri, J. K., Putri, R. N., Christanti, R., & H. L. Nugroho, A. (2024). Green Banking Universe and Sustainability Banking Industry in Indonesia: The Influence of Information Technology Governance. *Indonesian Journal of Sustainability Accounting and Management*, *8*(1), 165-177. https://doi.org/10.28992/ijsam.v8i1.892

Qwader, A. S. Y., Al-Rawashdeh, E. T., Al-Badaineh, G., & Al-Oshaibat, S. D. (2025). The Impact of Information and Communication Technology (ICT) on Marketing Performance in Islamic Banks: Empirical Evidence from Southern Jordan. *International Review of Management and Marketing*, *15*(5), 393-400. https://ideas.repec.org/a/eco/journ3/v15y2025i5id19928.html

Rahmamita, D., & Kahar, M. R. (2024). Green Banking Disclosure and Financial Performance: Role of Corporate Governance as Moderating Variable. *Journal of Management and Administration Provision*, *4*(3), 392-401. https://doi.org/10.55885/jmap.v4i3.443

Ray, K. (2024). Capital Structure and Profitability of Indian Computer Firms. In *Contemporary Issues in International Trade: Challenges and Opportunities* (Vol. 3, pp. 235–246). Emerald Publishing Limited. https://doi.org/10.1108/978-1-83797-320-020241015

Riswanto, A., Joko, Napisah, S., Boari, Y., Kusumaningrum, D., Nurfaidah, & Judijanto, L. (2024). *Ekonomi bisnis digital: Dinamika ekonomi bisnis di era digital*. PT. Sonpedia Publishing Indonesia. https://buku.sonpedia.com/2024/01/ekonomi-bisnis-digital.html

Saeed, Y. A. H., & Ahmed, R. A. (2023). The impact of information technology on the performance of commercial banks through the faithful representation of accounting information system. *International Journal of Professional Business Review: Int. J. Prof. Bus. Rev.*, *8*(9), 2. https://dialnet.unirioja.es/servlet/articulo?codigo=9091589

Siahaan, C., Silalahi, A. S., Syahyunan, S., & Sianipar, A. S. (2020). Analysis of Green Banking Sustainability And Financial Performance Implementation Towards Profitability of Banking Listed On The Indonesia Stock Exchange In 2012-2018. *Journal Of Management Analytical and Solution (JoMAS)*, *1*(1), 1-12. https://doi.org/10.32734/jomas.v1i1.5240

Tan, Y., Lin, B., & Wang, L. (2025). Green finance and corporate environmental performance. *International Review of Economics & Finance*, *98*, 103929. https://doi.org/10.1016/j.iref.2025.103929

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal, 18*(7), 509–533. https://doi.org/10.1002/(SICI)1097-0266(199708)18:7%3C509::AID-SMJ882%3E3.0.CO;2-Z

Van Thuy, N. (2021). ICT and bank performance: empirical evidence from Vietnam. *Journal of Contemporary Issues in Business and Government| Vol*, *27*(2), 4150. https://doi.org/10.47750/cibg.2021.27.02.433

Vuong, N. L., Pham, H. M., Le, T. T., Nguyen, V. C., & Nguyen, T. H. T. (2025). Information and communication technology as a catalyst for bank efficiency: Empirical evidence from Vietnam. *Asia and the Global Economy*, *5*(2), 100119. https://doi.org/10.1016/j.aglobe.2025.100119

Walzer, M., Tamimi, A., & Firmansyah, A. (2024). Are Banking Financial Performances and Green Banking Disclosure Associated with Bank Profitability? *Accounting Student Research Journal*, *3*(1), 55-71. https://doi.org/10.62108/asrj.v3i1.7645

Watts, R. L., & Zimmerman, J. L. (1990). Positive Accounting Theory: A Ten Year Perspective. *The Accounting Review*, *65*(1), 131-156. https://doi.org/10.2308/TAR-9603274032

Weber, O. (2017). Corporate sustainability and financial performance of Chinese banks. *Sustainability Accounting, Management and Policy Journal*, *8*(3), 358-385. https://doi.org/10.1108/SAMPJ-09-2016-0066

West, S. G., Aiken, L. S., & Krull, J. L. (1996). Experimental personality designs: Analyzing categorical by continuous variable interactions. *Journal of Personality, 64*(1), 1–48. https://doi.org/10.1111/j.1467-6494.1996.tb00813.x

White, H. (1980). A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity. *Econometrica*, *48*(4), 817-838. https://doi.org/10.2307/1912934

Vol: 18 **No:** 03 **Year:** 2026 **ISSN:** 1309-8055 (Online) (**pp.** 323-351) **Doi:** 10.34109/ijefs.2026180314

Wooldridge, J. M. (2010). *Econometric Analysis of Cross Section and Panel Data* (2nd ed.). MIT Press. https://mitpress.mit.edu/9780262232586/%0D%0A

Xiliang, Q., Kuo, Y.-K., Abourehab, M. A. S., Mabrouk, F., Ramirez-Asis, E., Abdul-Samad, Z., & Makes, N. (2023). The impact of ICT, green finance, and CSR on sustainable financial performance: moderating role of perceived organizational support. *Economic Research-Ekonomska Istraživanja*, *36*(3), 2151489. https://doi.org/10.1080/1331677X.2022.2151489

Xu, F., Kasperskaya, Y., & Sagarra, M. (2025). The impact of FinTech on bank performance: A systematic literature review. *Digital Business*, *5*(2), 100131. https://doi.org/10.1016/j.digbus.2025.100131

Zadeh, F. O., & Eskandari, A. (2012). Firm size as company's characteristic and level of risk disclosure: Review on theories and literatures. *International Journal of Business and Social Science,* *3*(17), 9–17. https://www.ijbssnet.com/journals/Vol_3_No_17_September_2012/2.pdf