

ESG performance and firm performance: The mediating role of green technology innovation disclosure in Indonesian Firms

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ABSTRACT

The increasing necessities of sustainable development has driven attention towards the relationship between Environmental, Social, and Governance (ESG) and firm financial performance, specifically for environmentally sensitive sectors. The available empirical results are still limited, and very few studies particularly examine whether Green Technology Innovation Disclosure (GTID) can act as a mediator between ESG and firm performance in emerging markets. This research attempts to examine the relationship between ESG and firm performance while testing the mediating role of GTID on energy and industrial companies listed on Indonesia Stock Exchange (IDX). Using a balanced panel data set of 82 companies over 4 years (2021-2024) with total 328 observations, by employing fixed-effects panel regression and the Generalized Structural Equation Modeling (GSEM) with 5,000 bootstrap replications estimate the indirect effect. The result indicated Insufficient evidence of a positive association between ESG and return on assets (ROA) that statistically significant at 10 percent. However, this relationship is sensitive to alternative specifications, as the ESG coefficient becomes statistically insignificant when return on equity (ROE) is used and is statistically significant only around the median of the conditional ROA distribution. More importantly, ESG performance is not significantly associated with GTID, GTID is not significantly associated with ROA, and the bootstrapped indirect effect is statistically insignificant. Thus, the findings do not support GTID as a mediating mechanism between ESG performance and firm performance. The study highlights the importance of distinguishing disclosure-based green technology measures from the substantive implementation and economic intensity of actual green technological innovation when evaluating their financial implications.

Keywords: ESG performance; Firm performance; Green technology innovation disclosure; Corporate sustainability; Indonesia

JEL Classification: M14, Q56, L25

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1. Introduction

The importance of Environmental, Social, and Governance (ESG) performance has increased as ESG has become an important indicator of firms' sustainable development and long-term performance. Financial regulators, investors, and other stakeholders increasingly consider ESG performance alongside

financial indicators when assessing a company's long-term success and making investment and resource-allocation decisions (Wang et al., 2022). The growing emphasis on ESG performance encourages firms to integrate ESG considerations into their strategic decision-making processes (Chen et al., 2024a; Chen et al., 2024b; Ivic et al., 2021). This trend is particularly relevant given growing concerns about climate change and environmental degradation caused by human activities. The public increasingly expects companies to strengthen their environmental practices in daily production and operational activities, which may influence firms' strategic decisions and, consequently, their performance (Song et al., 2024).

Although ESG performance is increasingly recognized for its potential benefits, empirical evidence on its relationship with firm performance remains mixed (Abady & Hermawan, 2025). The financial benefit of ESG performance has been found in some studies (Aydoğmuş et al., 2022), while being insignificant or even having adverse effects in other studies (Devianti, 2025; Rikandi & Silvia, 2023). These mixed findings suggest that the ESG-firm performance relationship may depend on intervening mechanisms or other contextual conditions (Engko & Rahmiati, 2025; Widoretno et al., 2025). Therefore, solely observing the relationship between ESG performance and firm performance may leave an incomplete result of the financial consequences of ESG activities (Silviani et al., 2024).

Another potential underlying mechanism may be green technology-related corporate activity (He et al., 2023). Previous research indicates that green innovation may contribute to operational efficiency, resource productivity, competitive advantages, and proactive responses to environmental challenges (Lian et al., 2023; Melander & Arvidsson, 2022). However, existing literatures concentrate mostly on actual green innovation/technological investments, with less emphasis on the practice in which firms' green technology innovation activities can be conditioned in the link between the ESG and the firm performance (Liang & Park, 2024). This distinction matters because disclosure-based measures may not necessarily reflect the actual implementation or the economic intensity of technological innovation.

Therefore, the present study considers green technology innovation disclosure (GTID), which captures the extent to which firms publicize green technology-related activities in their corporate disclosures, as an additional underlying process (Rahayuningsih et al., 2025). GTID can potentially act as a signaling device that reduces the information asymmetry between the management and the external investors and eases the uncertainty with respect to the claims made by the firm about its ownership of sustainable innovation. Even so, whether it can be a channel for the ESG to be associated with better financial performance remains empirically untested, particularly in emerging markets (Tripopsakul, 2025).

This problem is especially important in the case of Indonesia, where environmental pressures related to economic and industrial activity exist (Liu et al., 2025; Rahayuningsih et al., 2025). Indonesia is among the world's largest greenhouse gas emitters, with reported emissions of approximately 1.32 billion tons of carbon dioxide equivalent in 2024. Energy and industrial companies are particularly relevant because their activities are closely associated with carbon emissions, resource consumption, and environmental externalities (Islahuddin et al., 2026). These issues have been widely studied and have also subjected companies to increasing pressure from regulators, investors, and other stakeholders to improve their sustainability performance (Ramadhan et al., 2023; Shafitranata et al., 2026). While previous research has considered concepts of ESG, green innovation, and firm performance within the Indonesian context (Dewanti & Susila, 2024; Mardiana & Hanani, 2025), more evidence on whether the GTID concept mediates the impact of ESG performance on firm's performance within environmentally sensitive industries in Indonesia remains limited.

To address this Issue, this study aims to examine the nexus between ESG and firm performance and whether Green Technology Innovation Disclosure (GTID) as a disclosure-based mechanism in

mediating the relationship between ESG and firm performance for the energy and industrial firms listed in the Indonesia Stock Exchange (IDX) from 2021 to 2024. By examining 82 firms from two environmentally sensitive industries, this study expands the existing research which has predominantly looked into one industry only, or has investigated green innovation while not differentiating between actual innovation and disclosure-based green innovation.

This study makes contribution in two folds. First, it adds value to the existing literature by providing empirical evidence on the ESG-firm performance relationship in emerging economy, and environmentally sensitive sectors. Second, it clarifies the potential role of GTID as disclosure-based phenomenon, as opposed to the actual effect of green technology innovation, in mediating the impact of ESG on firm performance (Putra et al., 2025). Stakeholders and practitioners including managers, investors, and government authorities may find this research helpful to determine whether disclosing green technology innovation is an economically meaningful mechanism linking ESG with firm performance.

2. Theoretical Framework

ESG Performance and Firm Performance

According to stakeholder theory, companies create long-lasting corporate value by satisfying the needs and expectations of many stakeholders around them (Dameri & Ferrando, 2021). From this standpoint, assuming and reporting ESG risks and opportunities might create or enhance stakeholder relationships with investors, employees, regulators, and other stakeholder groups. High level of disclosure and execution of ESG might be a driven by the company's high responsibility, through elaborating transparency and accountability, and subsequently make stakeholders trust the company more. All of the above can result in an improved company image, more robust stakeholder relationships, and competitive advantage, which ultimately could contribute to improved company performance (Aydoğmuş et al., 2022; da Cunha et al., 2025).

However, not all evidence suggests that the relationship between ESG performance and firm performance is necessarily positive. Prior to the activity, initially small but positive incremental costs may be added to its provision, arising from expenditures related to environmental compliance, cleaner technologies, employee benefits, governance improvements, monitoring schemes, and sustainability reporting. The incurred costs could also have the effect of increasing operating or administrative expenses in the early stage of the implementation process and of conflicting with the more clearly profitable uses of funds, thus increasing the company's expenses in the short run. Therefore, even the provision of the activities involving ESG may derive many benefits to the firm, the latter's economic benefit may take a while to manifest, and be only partially offset by the additional costs incurred to provide the activities.

This trade-off is evident in empirical studies. Several studies have shown the potential for ESG performance to enhance firm performance (Aydoğmuş et al., 2022; Makhdalena et al., 2023; Xue et al., 2026), while concurrently shows that the positive impact of ESG on firm performance are not always realized or linear. For example, Teng et al. (2022) highlight that engaging in excessive levels of ESG can instead generate diminishing financial gains, suggesting the costs of implementing sustainability initiatives can potentially offset a part of the benefits. Stakeholder theory suggests that ESG performance may contribute to firm performance by strengthening stakeholder relationships and corporate reputation, although implementation costs may attenuate these benefits in the short run. Accordingly, this study expects a positive, although potentially modest, association between ESG performance and firm performance.

H₁: ESG performance is positively associated with firm performance.

The Mediating Role of Green Technology Innovation Disclosure

Signaling theory explains how firms disclose information to external stakeholders to mitigate information asymmetry between corporate members and external parties and convey information about their strategies, commitments, and future prospects. In the sustainability context, firms may use corporate disclosures to communicate their environmental orientation and demonstrate how sustainability considerations are incorporated into their strategic activities (Liu et al., 2025). Thus, Green Technology Innovation Disclosure (GTID) could be considered as a means of information signals, which are transmitted by firms to inform investors and other stakeholders of the firms' undertaking of environmentally focused innovations.

This distinction is important because GTID does not directly reflect the real magnitude of green technological innovation conducted inside a company. It actually reflects firms' dissemination of knowledge about green technology-related activities in the form of disclosures when drafting corporate reports. Firms may demonstrate their green technology-related activities in an effort to conduct green movements, such as related to eco-friendly technologies, energy saving technologies, emission reduction/cleaner production technologies, resource saving technologies, or other technology-based environmental practices, without such disclosures necessarily being able to mirror how much green patent, R&D investment or capital investment related to green technologies a firm actually incurs. In this regard, this paper explicitly treats Green Technology Innovation Disclosure, rather than Green Technology Innovation itself, as the mediating variable.

From a signaling viewpoint, an organization with good ESG performance has stronger motivation to disclose information regarding sustainability activities to outside stakeholders. Better ESG performance indicates a higher level of concern for ESG information and may also lead to providing more green-related disclosures. By providing information about such initiatives, firms can make their ESG commitments more observable and reduce uncertainty regarding the substance of their sustainability strategies (Ren et al., 2024). Thus, GTID may function as one of the communication channels through which ESG performance is conveyed to the market.

GTID may subsequently be associated with firm performance through its informational effects. More extensive and credible disclosure of green technology-related initiatives can reduce information asymmetry, enhance stakeholder understanding of the firm's environmental strategy, and strengthen perceptions of corporate commitment to sustainability. Improved transparency may contribute to stakeholder trust, corporate reputation, investor confidence, and continued access to financial and non-financial resources, which may ultimately support firm performance. Previous studies have also suggested that green innovation-related information and sustainability-oriented technological activities can play an important role in connecting ESG practices with corporate outcomes (Chen et al., 2024a; Chouaibi et al., 2021).

However, the mediating role proposed in this study emphasized the disclosure channel rather than the economic effect of actual technological innovation. GTID may communicate sustainability-related technological efforts to stakeholders, but such disclosure does not guarantee that the disclosed initiatives have been implemented at sufficient scale to generate operational efficiencies or immediate financial benefits. Thus, the function of GTID as a valid indicator of association between ESG and firm performance is an empirical matter. This issue is especially significant in the Indonesian setting where the relatively divergent sustainability practices, reporting quality and actual employment of green technology would affect stakeholder perception of corporate environmental reporting.

In accordance with the signaling theory and previous argumentation, it is hypothesized that a more solid ESG performance will stimulate greater disclosure of green technology-related initiatives and such disclosure, in turn, would positively influence stakeholder perception and firm performance.

H₂: Green Technology Innovation Disclosure mediates the relationship between ESG performance and firm performance.

Based on the above reasoning and hypotheses, this study establishes the conceptual framework of ESG performance, Green Technology Innovation Disclosure, and firm performance. In particular, ESG performance can be directly related to firm performance and can be indirectly related to firm performance via GTID.

3. Methodology

Sample

A quantitative design using balanced panel data is employed to examine the association between ESG performance and financial performance and to test whether GTID serves as a mediating mechanism in this relationship. The empirical sample consists of firms in energy and industrial sectors listed on Indonesia Stock Exchange. These sectors are particularly chosen since the activities of these companies are prone to environmental stress, including its consumption of resources, emissions, and increasing demands from the stakeholders' expectations regarding the sustainability of the company.

The four-year observation period covers 2021–2024. The initial population consisted of 113 energy and industrial firms that were continuously listed on the IDX throughout the observation period. Of these, 11 firms were excluded because the unavailability of disclosed consecutive financial statements and sustainability reports, which were required for the development of the study variables. A further 20 firms were excluded because the unavailability of disclosed consecutive sustainability reports throughout the observation period. Therefore, the final sample consisted of 82 firms, resulting in 328 firm-year observations. Table 1 presents the systematic sample selection process.

Table 1. Sample selection criteria

Criteria	Total
Energy and industrial firms consistently listed on the Indonesia Stock Exchange (IDX) throughout the 2021–2024 period	113
Firms that did not publish consecutive financial statements during the observation window	(11)
Firms that did not release consecutive sustainability reports across the 2021–2024 timeframe	(20)
Final eligible samples	82
Total observations (82 firms x 4 years)	328

Data Source

The secondary data is gathered from firm reports and financial databases. Data on ESG performance is sourced from Bloomberg database and specifically use Bloomberg Overall ESG Score for this purpose. Data on GTID are manually collected from the annual reports. Financial and operational data used for making performance and control variables are extracted from corporate financial statements.

This distinction between ESG performance and GTID underpins the empirical design of the study. ESG performance provides an overall measure of a firm's financially significant management practices related to environmental, social, and governance issues, whereas GTID measures the extent to which a firm discloses information about its green technology activities. Accordingly, GTID is treated as a disclosure-related variable rather than a measure of actual technology inputs, green patents, green R&D, related environmental expenditures, or the intensity of firms' green technological innovation

strategies. This treatment is consistent with the theoretical framework of the study, which explicitly distinguishes Green Technology Innovation Disclosure from actual Green Technology Innovation.

Variable Measurement

The main dependent variable is firm performance, measured by Return on Assets (ROA), which reflects a firm's ability to generate earnings relative to its total assets. ROA is used as the key dependent variable in the main regression models.

Table 2. Variable measurement

Variables	Abbr.	Measurement/Formula	Source(s)
Firm Performance	ROA	$ROA = \frac{\text{Net income}}{\text{Total Assets}}$	(Astuti et al., 2021)
ESG Performance	ESG	ESG aggregate score derived from the Bloomberg database (Scale: 0–10)	(Christiawan Y. J., 2026)
Green Technology Innovation Disclosure	GTID	$GTID = \frac{\text{Number of disclosed GTI indicators}}{\text{Total applicable GTI indicators}}$	(Dewi et al., 2024; Xie et al., 2019)
Gross Profit Margin	GPM	$GPM = \frac{\text{Gross Profit}}{\text{Total Revenue}}$	(Chen et al., 2024b)
Asset Turnover	ATO	$ATO = \frac{\text{Total Revenue}}{\text{Total Assets}}$	(Chen et al., 2024b)
Cash Flow Ratio	CFR	$CFR = \frac{\text{Net Cash Flow from Operating Activities}}{\text{Total Assets}}$	(Chen et al., 2024b)
Revenue Growth Rate	REVG	$REVG = \frac{\text{Current Year Revenue} - \text{Prior Year Revenue}}{\text{Prior Year Revenue}}$	(Chen et al., 2024b)
Asset Growth Rate	ASSETG	$ASSETG = \frac{\text{Current Year Total Assets} - \text{Prior Year Total Assets}}{\text{Prior Year Revenue}}$	(Chen et al., 2024b)
Institutional Ownership	INST	$INST = \frac{\text{Total shares held by institutional investors}}{\text{Total outstanding shares}}$	(Chen et al., 2024b)

ESG performance is measured using the Bloomberg Overall ESG Score, which ranges from 0 to 10, with higher scores indicating better ESG performance. The Bloomberg Overall ESG Score reflects how well a firm addresses financially material ESG risks and opportunities relative to its industry peers. The scoring methodology incorporates all available sources of information, including the extent and comprehensiveness of corporate disclosures. In this study, however, the scaled score is used solely as a measure of ESG performance rather than as a measure of ESG disclosure.

Green Technology Innovation Disclosure (GTID) measures the extent to which firms disclose information on environmentally oriented technological innovation in their corporate reports. Accordingly, GTID captures the extent of disclosure rather than the extent or effectiveness of technological innovation itself.

Firm-level control variables that may be associated with both firm performance and GTID are included in the analysis. These variables comprise Gross Profit Margin (GPM), Asset Turnover (ATO), Cash Flow Ratio, Revenue Growth, Asset Growth, and Institutional Ownership (INST). Detailed definitions, measurement formulas, and references for all variables are presented in Table 2.

Empirical Analysis

The empirical analysis was conducted in several stages. First, descriptive statistics are used to describe and compare the distribution, central tendency, and dispersion of the variables. Second, Pearson correlation analysis is conducted to provide preliminary evidence of the bivariate relationships among the variables and identify potential signs of multicollinearity. Finally, panel data regression is employed to examine the direct relationship between ESG performance and firm performance, as well as the component relationships within the proposed mediation process.

Panel Data Model Selection

Given the longitudinal structure of the dataset in which combines cross-sectional observations across firms with repeated observations over time, panel data estimation is employed to control for unobserved firm-specific heterogeneity.

Model selection is conducted using the Chow test and the Hausman test. The Chow test is used to compare the Common Effect Model or pooled OLS specification with the Fixed Effects Model. The Hausman test is then used to determine whether the Fixed Effects Model or Random Effects Model is more appropriate. The reported results favor the Fixed Effects Model across the three principal equations, and therefore the fixed-effects estimator is used as the primary panel-data specification.

Fixed-Effects Regression Models

The first model examines the direct association between ESG performance and firm performance and is used to test Hypothesis 1 (Equation 1/Eq. 1).

$$ROA_{it} = \alpha + \beta_1 ESG_{it} + \sum_{k=1}^K \gamma_k Control_{kit} + \mu_i + \varepsilon_{it} \quad (\text{Eq. 1})$$

Where denotes firm performance for firm in year , represents ESG performance, denotes the set of firm-level control variables, captures time-invariant firm-specific effects, and represents the idiosyncratic error term.

Hypothesis 1 is evaluated by examining the sign and statistical significance of . A positive and statistically significant coefficient is interpreted as evidence of a positive association between ESG performance and firm performance. Results significant only at the 10 percent level are interpreted as marginal or weak statistical evidence.

The second model examines the first component of the proposed mediation pathway by estimating the association between ESG performance and GTID (Equation 2/Eq. 2).

$$GTID_{it} = \alpha + \beta_1 ESG_{it} + \sum_{k=1}^K \gamma_k Control_{kit} + \mu_i + \varepsilon_{it} \quad (\text{Eq. 2})$$

This specification evaluates whether within-firm changes in ESG performance are associated with corresponding changes in GTID. The third model incorporates both ESG performance and GTID into the firm-performance equation (Equation 3/Eq. 3).

$$ROA_{it} = \alpha + \beta_1 ESG_{it} + \beta_2 GTID_{it} + \sum_{k=1}^K \gamma_k Control_{kit} + \mu_i + \varepsilon_{it} \quad (\text{Eq. 3})$$

This model evaluates whether GTID is associated with firm performance after controlling for ESG performance and other firm-level characteristics.

These component regressions are used to assess the relationships underlying the proposed mediation mechanism. However, mediation is not inferred solely from the significance or insignificance of the individual coefficients. The indirect effect is formally tested using GSEM with bootstrap estimation.

Mediation Analysis

To test Hypothesis 2, this study employs Generalized Structural Equation Modeling (GSEM). The mediation framework evaluates whether ESG performance is indirectly associated with firm performance through Green Technology Innovation Disclosure. The proposed mediation process consists of two principal component paths.

$$\begin{aligned} ESG &\rightarrow GTID \\ \text{and} \\ GTID &\rightarrow ROA \end{aligned}$$

While the direct ESG–ROA relationship is retained in the empirical specification. The indirect effect is expressed as Equation 4 (Eq. 4).

$$\text{Indirect Effect} = a \times b \quad (\text{Eq. 4})$$

Where a represents the estimated association between ESG performance and GTID and b represents the estimated association between GTID and firm performance conditional on ESG performance and the included control variables.

Since the sampling distribution of an indirect effect may deviate from normality, statistical inference is based on bootstrap estimation. A total of 5,000 bootstrap replications is used to construct the confidence interval for the indirect effect. Hypothesis 2 is empirically supported only when the bootstrap confidence interval does not include zero. If the confidence interval contains zero, the indirect effect is interpreted as statistically insignificant, thus proposed mediating role of GTID is not supported. The use of 5,000 bootstrap replications is consistent with the mediation procedure described in the study.

Diagnostic Tests and Robust Standard Errors

Several diagnostic procedures were conducted before interpreting the panel regression results. Multicollinearity is assessed using the Pearson correlation matrix and the Variance Inflation Factor (VIF). The correlation matrix provides an initial indication of collinearity among the explanatory variables, while VIF statistics provide a more formal assessment. Heteroscedasticity is also examined in the three panel regression models.

Because the diagnostic results indicate the presence of heteroscedasticity, the fixed-effects regressions are estimated using firm-clustered robust standard errors, with clustering at the firm level. This specification allows the error terms to be heteroscedastic and correlated within the same firm over time while maintaining independence across firms. The use of firm-clustered robust standard errors does not change the estimated regression coefficients but provides statistical inference that is robust to within-firm error dependence and heteroscedasticity. Because the main regressions are estimated using fixed-effects specifications, the reported R^2 values are interpreted as within R^2 , representing the proportion of within-firm variation over time explained by the included regressors.

Robustness Tests

Two robustness analyses were conducted to evaluate the sensitivity of the principal findings. First, Return on Equity (ROE) is used as an alternative measure of firm financial performance. This test evaluates whether the observed association between ESG performance and firm performance, as well as the conclusion regarding GTID mediation, remains similar when profitability is measured relative to shareholders' equity instead of total assets. Second, quantile regression is employed to investigate whether the estimated relationships vary across different parts of the conditional distribution of firm profitability. The analysis focuses on the 25th, 50th, and 75th conditional quantiles.

For the ESG–ROA relationship, Q25, Q50, and Q75 refer to different positions in the conditional distribution of ROA, rather than to categories of ESG performance or firm size. Thus, the quantile analysis is used to examine whether the ESG–ROA association differs between relatively lower, median, and higher levels of conditional profitability. For the mediation-related specifications, quantile regression is interpreted as a supplementary robustness analysis of the component relationships underlying the proposed mediation mechanism. It examines whether the ESG–GTID and GTID–ROA relationships remain consistent across the examined conditional quantiles. Formal inference regarding the indirect mediating effect, however, remains based on the GSEM bootstrap procedure because the paper does not estimate a separately bootstrapped indirect effect at each quantile.

Interpretation of the Empirical Estimates

Observational panel-data approach was employed so that the estimated coefficients should mainly be seen as correlations. Additionally, the fixed-effects estimator controls for unobserved, time-invariant firm heterogeneity; however, it cannot correct for all types of endogeneity. Unobserved, time-varying omitted variables, reverse causality, and measurement error, are still not dealt with.

This interpretation is in accordance with the scope of the study and the limitations identified in the paper. Hence, the empirical strategy aims to measure within-firm correlations in between firm performance measured in ESG and GTID, so as not to overestimate causal relationships.

4. Results

Descriptive Statistics

Table 3 presents the descriptive statistics for the variables employed in the empirical analysis. Return on Assets (ROA) which is the primary measure of firm performance has a mean of 0.054 and standard deviation of 0.087, with minimum and maximum values of -0.246 and 0.341, respectively. This implies that the sampled firms could have on average a return on assets of about 5.4 percent. The measurement of ROA is also expected to show large variations in the firm-year observations profitability.

The average ESG score is 5.307, with a standard deviation of 2.922 and the scores ranging from a minimum of 0.08 to a maximum of 9.93. Given the scale employed by the Bloomberg ESG score (0-10) as well as the large standard deviation, it can be inferred that the average company's ESG score is situated within the middle of the range.

Green Technology Innovation Disclosure (GTID) has a mean of the value is 0.660, the standard deviation is 0.241 and the minimum and maximum values are 0 and 1, respectively. The above statistics indicate that the observed positive disclosure (mean value) among the sampled firms accounts for around 66 percent of all disclosure items in the GTID index. The standard deviation suggests relatively low variance in green technology disclosure.

The control variables all vary substantially across the sample. Revenue Growth displays a fairly large level of dispersion, with an average of 0.316, a standard deviation of 1.095 and a maximum of 13.592, whilst Gross Profit Margin ranges from 5.838 to 1.000. These descriptive data highlight that the firms under investigation vary substantially in terms of their operational and financial dynamics, which I go on to investigate in the multivariate panel-data analysis.

Table 3. Descriptive statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
ROA	328	.054	.087	-.246	.341
ESG	328	5.307	2.922	.08	9.93
GTID	328	.66	.241	0	1
GrossProfitMargin	328	.217	.437	-5.838	1
ATO	328	.75	.562	.001	3.461
Cashflow	328	.092	.105	-.309	.508
RevenueGrowth	328	.316	1.095	-.817	13.592
AssetGrowth	328	.107	.233	-.533	1.725
INST	328	.64	.23	0	.993

Pearson Correlation Analysis

Table 4 shows the Pearson correlation matrix for the variables used in the empirical study. The correlation between ESG performance and ROA indicates a positive result but statistically insignificant ($r=0.036$). The bivariate analysis, therefore, was unable to provide statistical evidence in support of the existence of a linear relationship between ESG performance and firm profitability.

Conversely, the correlation between Green Technology Innovation Disclosure (GTID) and firm profitability (measured by ROA) is positive and statistically significant ($r = 0.145$, $p < 0.01$), but the correlation coefficient shows a weak positive bivariate relationship between GTID and firm profitability. Furthermore, the correlation coefficient between ESG and GTID is also positive but statistically insignificant ($r = 0.082$). Thus, the positive bivariate association between ESG and GTID at this level is weaker.

Table 4. Pearson correlation analysis

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) ROA	1.000								
(2) ESG	0.036	1.000							
(3) GTID	0.145***	0.082	1.000						
(4) GrossProfitMargin	0.231***	0.013	0.179***	1.000					
(5) ATO	0.233***	0.092*	-0.087	-0.037	1.000				
(6) Cashflow	0.594***	0.060	0.214***	0.227***	0.102*	1.000			
(7) RevenueGrowth	0.060	0.047	-0.011	0.100*	0.015	0.066	1.000		
(8) AssetGrowth	0.331***	-0.031	0.017	0.140**	0.221***	0.156***	0.263***	1.000	
(9) INST	0.068	-0.040	0.020	-0.101*	0.065	0.001	-0.033	0.037	1.000

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Among the control variables, Cash Flow exhibits the strongest positive correlation with ROA ($r = 0.594$, $p < 0.01$), followed by Asset Growth ($r = 0.331$, $p < 0.01$), ATO ($r = 0.233$, $p < 0.01$), and Gross Profit Margin ($r = 0.231$, $p < 0.01$). All pairwise correlation coefficients are below 0.80, providing no preliminary indication of severe multicollinearity. This issue is further assessed using the Variance Inflation Factor (VIF) test in the subsequent diagnostic analysis.

Panel Data Model Selection

Several tests have been employed in order to determine the best specification in panel data using standard diagnostic tests in economics. To begin with, the Chow test was used to determine whether the Fixed Effects Model (FEM) has a better fitting compared to the Common Effect Model (CEM/Pooled OLS). In this case, p-values for model one, model two, and model three were 0.0000 which is far lower than the common 0.05 significance level. Consequently, there is enough evidence to reject the null hypothesis and conclude that FEM gives a better fit compared to the initial CEM.

Furthermore, to make the choice between the Fixed Effects and Random Effects Model (REM), Hausman test has been applied. The p-value of 0.0000, 0.0479 and 0.0000 obtained for the three models are below the 5 percent alpha value. It is therefore indicated that FEM should be adopted. The Hausman test rejects the null hypothesis underlying the random-effects specification, thereby supporting the use of the fixed-effects estimator.

All of the tests consistently indicate that the Fixed Effects Model (FEM) is the most appropriate estimation method for the empirical equations. As the test results do not support the use of either the Common Effects Model (CEM) or the Random Effects Model (REM), the Breusch–Pagan Lagrange Multiplier (LM) test is not required.

Table 5. Panel data model selection

	Chow test			Hausman test	
	Cross-section F-stat	Prob.		Chi-Sq. Statistic	Prob.
Model 1	5.78	0.0000	Model 1	104.06	0.0000
Model 2	21.23	0.0000	Model 2	14.19	0.0479
Model 3	5.78	0.0000	Model 3	115.83	0.0000

Diagnostic Tests

Multicollinearity test

The results of the multicollinearity test are presented in Table 6. All independent variables included in Models 1, 2, and 3 satisfy the established econometric criteria. This is supported by the Variance Inflation Factor (VIF) values, which are consistently below the commonly accepted threshold of 10. Similarly, the tolerance values for all independent variables remain above the minimum threshold of 0.10. These results indicate that the models do not exhibit problematic multicollinearity.

Heteroscedasticity test

The test for heteroscedasticity in Table 7 resulted in all p-values for models 1, 2, and 3 are found to be 0.0000. Since all these values fall below the significance level of 5 percent, therefore, the null hypothesis of homoscedasticity is rejected. This implies that heteroscedastic variance exists in all models. Because the diagnostic results indicate heteroscedasticity across the three specifications, the

fixed-effects models are estimated using firm-clustered robust standard errors. Clustering at the firm level allows for heteroscedasticity and within-firm correlation in the error terms over time, by which providing more reliable statistical inference for the panel-data structure. The use of such an econometric technique does not change the value of coefficients; however, it changes the values of standard errors and hence makes the results robust to heteroscedasticity.

Panel Data Regression Results and Hypothesis Testing

Table 8 presents the results of the fixed-effects panel regression analysis. In Model 1, ESG performance is positively associated with ROA ($\beta = 0.001763$, $p = 0.087$). Because the coefficient is statistically significant only at the 10 percent level, the result provides weak empirical support for Hypothesis 1. Thus, higher ESG performance is associated with higher within-firm ROA, although the statistical evidence remains marginal.

Table 6. Panel data regression

Variables	Model 1	Model 2	Model 3
	ROA	GTID	ROA
ESG	0.001763* (0.087)	-0.001460 (0.519)	0.001717* (0.097)
GTID	- -	- -	-0.031762 (0.234)
GrossProfitMargin	-0.000055 (0.998)	-0.004385 (0.444)	-0.000194 (0.992)
ATO	0.105331*** (0.000)	0.097358* (0.086)	0.108423*** (0.000)
Cashflow	0.169452*** (0.002)	0.004432 (0.924)	0.169593*** (0.002)
RevenueGrowth	-0.007870*** (0.004)	-0.001153 (0.799)	-0.007907*** (0.004)
AssetGrowth	0.044853** (0.014)	-0.027533 (0.165)	0.043978** (0.016)
INST	-0.019303 (0.482)	-0.007998 (0.943)	-0.019557 (0.473)
Constant	-0.040038* (0.052)	0.603494*** (0.000)	-0.020870 (0.415)
Observations	328	328	328
R-squared	0.2744	0.0347	0.2778
Number of Nama_Perusahaan	82	82	82
F-statistic	11.12	1.10	10.17
Prob > F	0.000	0.370	0.000

Firm-clustered robust p-values are reported in parentheses. Clustering is conducted at the firm level (82 firms) *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Model 2 examines the association between ESG performance and Green Technology Innovation Disclosure (GTID). The estimated ESG coefficient is negative, and, is not statistically significant ($\beta = -0.001460$, $p = 0.519$). This implies that changes in a firm's ESG performance over time are not consistently associated with changes in GTID in the sample period. Further, the overall model is not statistically significant (Prob $>F = 0.370$), and the within R is fairly low at 0.0347, and thus the model does not substantially explain the within variation of GTID.

Model 3 includes both ESG performance and GTID in explaining ROA. The coefficient of GTID is negative but statistically insignificant ($\beta = -0.031762$, $p = 0.234$), providing no statistically significant evidence that GTID is associated with ROA after controlling for ESG performance and other firm-level characteristics. Meanwhile, the ESG coefficient remains positive and marginally significant at the 10 percent level ($\beta = 0.001717$, $p = 0.097$).

Taken together, the panel regression results indicate that the component paths underlying the proposed GTID mediation mechanism are not empirically supported: ESG performance is not significantly associated with GTID, and GTID is not significantly associated with ROA. However, the statistical significance of the indirect effect cannot be determined solely from these component regressions and is therefore formally assessed using GSEM with bootstrap estimation in the subsequent mediation analysis.

Coefficient of Determination (R^2)

Since the models are estimated using fixed-effects regressions, the reported values are interpreted as within, reflecting the proportion of variation within the same firm over time that is explained by the explanatory variables included in each model. Model 1 reports a within of 0.2744, indicating that changes in ESG performance and the included control variables explain approximately 27.44 percent of the within-firm variation in ROA over the 2021–2024 period. Model 2 has a substantially lower within of 0.0347, indicating that ESG performance and the control variables explain approximately 3.47 percent of the within-firm variation in Green Technology Innovation Disclosure (GTID). Model 3 reports a within of 0.2778, suggesting that ESG performance, GTID, and the control variables jointly explain approximately 27.78 percent of the within-firm variation in ROA.

The remaining unexplained residual does not necessarily have to be explained away as being caused by other exogenous variables. It could contain missing time-varying factors, firm shocks, measurement error, reporting changes, model misspecification, or other variables not captured in the empirical specification. And since Model 2 has a small R^2 value for the within variation, this means that short-term variations in GTID are not strong explanations of ESG performance and the other firm controls, and is not meant as a critique of Model 2.

This interpretation aligns well with the mediating construct in this study. Global Transparency in Disclosure (GTID) is a disclosure-centric construct, and actions or modifications in disclosure behavior are likely to be affected by time-variant factors such as sustainability reporting strategies, regulatory mandates, stakeholder pressures, environmental accidents, technology investment decisions, and managerial communication policies. Since these factors are not fully captured in the current specification, the low explanatory power of Model 2 is therefore consistent with the possibility that GTID is shaped by a broader set of time-varying determinants. This also aligns with the empirical finding that ESG performance is not significantly associated with GTID and that GTID does not significantly mediate the ESG–firm performance relationship.

GSEM Mediation Test with Bootstrapping

The results of GSEM mediation analysis are presented in Table 9, which is confirmed using the bootstrap procedure with 5,000 repetitions. The coefficient of the indirect effect estimated is 0.0000538, reflecting the nominally positive direction of the indirect effect from ESG performance to firm performance through green technology innovation disclosure. At the same time, the confidence interval corrected for bias is -0.0001995; 0.0003071. Since this interval contains zero, it reflects the absence of statistical significance of the mediation effect.

In addition, the probability of this indirect effect being significant is 0.677 and is much larger than the generally used critical value of 0.05. The statistical result confirms that no statistically significant indirect effect of ESG performance on firm profitability (ROA) through GTID was found. Therefore, Hypothesis 2 (H2) is not empirically supported.

Table 7. GSEM mediation test with 5000 resample bootstrapping

Indirect	Coefficient	P-value	95% Confidence Interval	
			Lower	Upper
	0.0000538	0.677	-0.0001995	0.0003071

Robustness Test

To assess the stability and sensitivity of the primary empirical findings to alternative specifications, measurements, and estimation conditions, a series of robustness checks was conducted using two approaches. First, the dependent variable, Return on Assets (ROA), was replaced with Return on Equity (ROE) as an alternative measure of firm performance. Second, quantile regression analysis was employed to examine whether the proposed relationships remain consistent across different points of the conditional distribution of firm performance, rather than assuming that the relationships are uniform across the entire sample.

Alternative Dependent Variable: Return on Equity

For robustness, ROE was used as an alternative measure of firm financial performance. The results presented in Table 10 indicate that the coefficient for ESG performance remains positive but is statistically insignificant when firm performance is measured using ROE ($\beta = 0.0029254$, $p = 0.526$). This finding suggests that the marginally positive relationship between ESG performance and ROA observed in the baseline fixed-effects model does not persist when firm performance is measured using ROE. Therefore, the direct association between ESG performance and firm financial performance appears to vary depending on the profitability measure used, suggesting that caution is warranted when interpreting the baseline ESG coefficient in isolation.

The mediation results using the alternative ROE specification (see Table 8) are consistent with the finding above regarding the proposed mediating role of GTID. The estimated indirect effect of ESG performance on ROE through GTID is 0.0002601 and is statistically insignificant ($p = 0.541$). Although the estimated indirect effect changes in sign from the baseline ROA specification to the ROE specification, this difference is unlikely to affect the substantive inference because both estimates are statistically insignificant. Consistent with the GSEM results, the alternative specification provides no evidence that GTID mediates the relationship between ESG performance and firm performance. These findings therefore provide no additional empirical support for Hypothesis 2 under the alternative profitability measure examined in this study.

Table 8. Robustness test with alternative dependent variable

Models	Coefficient	p-value
ESG - ROE	0.0029254	0.526
ESG – GTID - ROE	-0.0002601	0.541

Quantile Regression Test

To further strengthen the analysis, the study employs quantile regression to examine how much the aforementioned estimated relationships could differ across various part of the conditional distribution of the dependent variables. Attention is paid to the 25 percent (Q25), 50 percent (Q50) and 75 percent (Q75) conditional quantile of the outcome variables and these three quantiles can be viewed as particular locations of the outcome variables' distribution conditional on the particular model specifications.

In Model 1, which analyses the relationship between ESG and ROA, the non-negative (and insignificant) coefficients at Q25 (0.00200), Q50 (0.00175) and Q75 (0.00152) show that the positive relationship between ESG and ROA can be detected at three conditional quantiles in the analysis. Yet, at the three quantiles, the statistical significance exists only at Q50 (10 percent significance level, $p = 0.076$). Q25 ($p = 0.106$) and Q75 ($p = 0.284$) do not exhibit the statistical significance, although the coefficients at the three quantiles are positive. These results indicate that the positive relationship can be observed at only the median quantile of the whole conditional ROA distribution, but the quantity does not support the positive relationship at the bottom and the top. Therefore, the quantile results imply the weak support of Hypothesis 1, not the positive relation between ESG and ROA.

For Model 2, which examines the relationship between ESG performance and GTID, the estimated coefficients for ESG performance across the 25th, 50th, and 75th quantiles are 0.00117, 0.00146, and 0.00171, respectively. However, none of these coefficients is statistically significant. Similar to the baseline fixed-effects results, the quantile regression analysis provides no evidence of a systematic relationship between ESG performance and GTID across different points of the conditional distribution of GTID. Therefore, the results provide no support for this component of the proposed mediating mechanism.

Model 3 analyzes the impacts of ESG, GTID, and ROA on the conditional ROA distribution. The pattern of the coefficients for ESG is similar to previous models, remaining positive across the three quantiles but only statistically significantly at Q50 at the 10 percent level ($= 0.00171$, $p = 0.083$), while estimates at the Q25 and Q75 quantiles are statistically insignificant. Estimates for GTID are, however, negative at the Q25, Q50 and Q75 quantiles ($= 0.0194$, 0.0323 , 0.0437 , respectively) though estimates at all quantiles are statistically insignificant. This is consistent with the baseline fixed-effects specification, which finds no statistically significant relationship between GTID and ROA.

Taken together, the quantile regression results indicate that the direct ESG–ROA association is heterogeneous across the conditional profitability distribution and is statistically detectable only around the median. In contrast, the relationships underlying the proposed GTID mediation mechanism remain statistically insignificant across the examined quantiles. The quantile analysis does not constitute any additional empirical support for the relationships among the component variables of ESG-GTID or GTID-ROA. The advantage of these quantile regressions is that they serve as robustness checks of the component relationships, rather than explicitly testing the indirect mediation effect. Hence, there is no formal inference test of Hypothesis 2 beyond the GSEM bootstrap analysis, which shows that the indirect mediation path of ESG performance on firm performance through GTID is insignificant.

Table 9. Quantile regression test

Variables	Model 1 (ESG – ROA)			Model 2 (ESG – GTID)			Model 3 (ESG – GTID - ROA)		
	ROA	ROA	ROA	GTID	GTID	GTID	ROA	ROA	ROA
	Q25	Q50	Q75	Q25	Q50	Q75	Q25	Q50	Q75
ESG	0.00200 (0.106)	0.00175* (0.076)	0.00152 (0.284)	-0.00117 (0.944)	-0.00146 (0.873)	-0.00171 (0.601)	0.00195 (0.127)	0.00171* (0.083)	0.00149 (0.285)
GTI	- (0.526)	- (0.169)	- (0.187)	-	-	-	-0.0194 (0.526)	-0.0323 (0.169)	-0.0437 (0.187)
Gross Profit Margin	0.00721 (0.738)	-0.000456 (0.979)	-0.00735 (0.766)	-0.00381 (0.935)	-0.00438 (0.863)	-0.00488 (0.593)	0.00744 (0.739)	-0.000537 (0.975)	-0.00755 (0.755)
ATO	0.111*** (0.000)	0.105*** (0.000)	0.0997*** (0.002)	0.126 (0.728)	0.0977 (0.619)	0.0718 (0.309)	0.113*** (0.000)	0.108*** (0.000)	0.104*** (0.001)
Cashflow	0.153*** (0.008)	0.170*** (0.000)	0.186*** (0.005)	-0.0157 (0.973)	0.00419 (0.987)	0.0221 (0.809)	0.155*** (0.009)	0.170*** (0.000)	0.183*** (0.00447)
Revenue Growth	-0.00674 (0.148)	-0.00793** (0.033)	-0.00900* (0.0919)	0.00362 (0.950)	-0.00110 (0.972)	-0.00533 (0.636)	-0.00693 (0.151)	-0.00795** (0.032)	-0.00885* (0.0906)
Asset Growth	0.0538*** (0.005)	0.0444*** (0.004)	0.0358 (0.106)	-0.0311 (0.852)	-0.0276 (0.760)	-0.0244 (0.452)	0.0525*** (0.009)	0.0436*** (0.005)	0.0358* (0.0995)
INST	-0.0501 (0.271)	-0.0176 (0.629)	0.0116 (0.824)	0.00166 (0.998)	-0.00788 (0.982)	-0.0165 (0.896)	-0.0544 (0.242)	-0.0180 (0.615)	0.0140 (0.780)
Observations	328	328	328	328	328	328	328	328	328

pval in parentheses *** p<0.01, ** p<0.05, * p<0.1

5. Discussion

The empirical results provide weak evidence of a positive relationship between ESG performance and firm performance, measured by Return on Assets (ROA). In the first fixed-effects baseline model, the coefficient for ESG performance is positive ($\beta = 0.001763$) and statistically significant at the 10 percent level ($p = 0.087$). Therefore, Hypothesis 1 receives only weak empirical support. The finding suggests that improvements in ESG performance tend to be associated with increases in within-firm profitability over time, which is broadly consistent with stakeholder theory. From this perspective, firms may improve their economic outcomes by addressing the expectations of stakeholders, including investors, employees, government regulators, and other relevant parties (Haryono & Wirianata, 2025; Setiani et al., 2024). Furthermore, greater emphasis on ESG-related factors may enhance transparency, stakeholder relationships, legitimacy, and reputation, which may subsequently support firms in achieving their financial objectives (Özer et al., 2023; Setiani et al., 2024; Siagian et al., 2026). However, the relatively modest effect and marginal statistical significance observed in this study indicate that these potential benefits may not translate into financial performance immediately or consistently.

One possible explanation for the weak ESG–ROA association is that the economic benefits of ESG practices may take time to materialize. Sustainability initiatives may require initial expenditures for

environmental compliance, governance improvements, reporting systems, cleaner technologies, and stakeholder engagement before generating measurable financial returns. This interpretation is consistent with the theoretical argument developed in this study that ESG implementation may involve a trade-off between short-term implementation costs and longer-term stakeholder and reputational benefits. Nevertheless, because the present models do not explicitly estimate lagged ESG effects, the time-lag explanation should be interpreted as a theoretically plausible explanation rather than a mechanism directly tested in this study (Chen et al., 2024b; Tang et al., 2022). The relatively short observation period of 2021–2024 may also limit the ability of the empirical design to capture the longer-term financial consequences of ESG implementation. This finding is broadly consistent with previous studies reporting positive but relatively weak or context-dependent associations between ESG performance and financial performance (Islahuddin et al., 2026; Özer et al., 2023; Siagian et al., 2026).

The robustness analyses further indicate that the direct ESG–firm performance relationship is sensitive to both the financial performance proxy and the conditional distribution of profitability. If ROA is replaced by ROE, the ESG coefficient remains positive but becomes statistically insignificant ($\beta = 0.0029254$, $p = 0.526$). Accordingly, the marginal ESG–ROA association observed in the baseline model should not be interpreted as evidence of a universally robust relationship across different profitability measures. The results rather suggest that the empirical relationship between ESG performance and financial performance depends partly on how firm performance is operationalized. Comparably, the outcomes for the quantile regression show that the statistically significant positive impact of the ESG variables to a large extent is observable only in the median of the conditional return on assets distribution at the 10 percent significance level, while the estimated effects at the lower and higher quantiles are statistically insignificant. These results indicate that the relation between the ESG and the ROA is unlikely to be homogeneous over different parts of the conditional distribution of the profitability. Therefore, the evidence supports a context-dependent and heterogeneous relationship rather than a consistently positive financial effect of ESG performance. The alternative ROE and quantile specifications consequently reinforce the need for caution when interpreting the baseline ESG coefficient.

The findings regarding Green Technology Innovation Disclosure provide no empirical support for the mediating mechanism proposed in Hypothesis 2. The mediation pathway fails at both of its principal component relationships. First, ESG performance has a negative but statistically insignificant association with GTID ($\beta = -0.001460$, $p = 0.519$), indicating that within-firm improvements in ESG performance are not systematically equipped by greater disclosure of green technology innovation during the observation period. Second, when GTID is included alongside ESG performance in the firm performance model, its coefficient also has a negative and statistically insignificant association ($\beta = -0.031762$, $p = 0.234$). Consistent with these results, the GSEM bootstrapping analysis produces an indirect effect of 0.0000538 with a p-value of 0.677 and a 95 percent confidence interval ranging from -0.0001995 to 0.0003071 . Since the confidence interval includes zero, there is no statistically significant indirect effect of ESG performance on ROA through GTID. Thus, Hypothesis 2 is not empirically supported.

The absence of mediation should not necessarily be interpreted as a contradiction of signaling theory. Instead, the results indicate that the specific signaling channel proposed in this study may not be supported in the sampled Indonesian energy and industrial firms. Signaling theory suggests that corporate disclosure can reduce information asymmetry when the information communicated is sufficiently informative, credible, and economically relevant to external stakeholders. However, GTID in the present study captures the extent to which firms disclose green technology-related activities rather than the scale, effectiveness, or economic productivity of actual green technology implementation.

This distinction is important because firms may disclose initiatives related to cleaner production, energy efficiency, emission reduction, and environmentally oriented technologies without such disclosures necessarily reflecting the magnitude of green R&D expenditures, capital investment, patents, or realized operational improvements. As a result, the level of disclosure may not be strong enough to lead to statistically significant increases in short-term profitability. This explanation is consistent with the conceptual separation clearly defined in this paper of: Green Technology Innovation Disclosure and Green Technology Innovation.

This distinction may also help explain why the present findings differ from earlier studies that report a mediating role of green innovation in the relationship between ESG performance and firm performance (Chen et al., 2024b; Chouaibi et al., 2021; Zhuang et al., 2026). Particular caution should be applied in interpreting these differences, as the previous studies use a construct of green innovation that is more closely related to actual technological innovation, whereas this study uses a disclosure-based measure. Additionally, the lack of a significant mediating effect of GTID does not imply that other types of actual green technological innovation are economically insignificant. Instead, green technology innovation disclosure does not have a statistically significant mediating effect on the relationship between ESG performance and profitability in this dataset. The relatively short four-year observation period may provide further explanation as the economic consequences of technological investment and innovation require longer periods to become observable (Chen et al., 2024b; Tang et al., 2022; Wang, 2024). However, because lagged technological effects are not explicitly modeled, this explanation should be regarded as a plausible interpretation rather than a mechanism directly tested in this study.

The difference between the bivariate correlation results and the fixed-effects estimates also provides useful insight into the role of firm heterogeneity. The Pearson correlation analysis provides a positive and statistically significant correlation between GTID and ROA, whereas the fixed-effects specification produces a negative but statistically insignificant GTID coefficient. This difference suggests that the simple correlation may partly reflect cross-sectional differences between firms rather than a systematic within-firm relationship over time. Since the fixed-effects estimator controls for time-invariant firm-specific characteristics and incorporates the control variables included in the empirical specification, the regression results provide stronger evidence for evaluating whether changes in GTID within a firm are associated with corresponding changes in profitability. Under this specification, no such statistically significant relationship is observed.

The robustness analyses provide additional support for the conclusion that GTID does not mediate the relationship between ESG performance and firm performance. Replacing ROA with ROE does not produce a statistically significant indirect effect of ESG performance through GTID. Although the sign of the estimated indirect effect changes under the ROE specification, it remains statistically insignificant. Likewise, the quantile regression analysis shows that the ESG–GTID relationship and the GTID–ROA relationship remains statistically insignificant across the examined quantiles. Thus, while the direct ESG–performance relationship displays sensitivity to alternative performance measures and different parts of the profitability distribution, the absence of empirical support for the GTID mediation pathway is comparatively more stable across the alternative specifications examined in this study.

The combined findings provide a more disaggregated interpretation of the relationship between ESG performance, GTID, and firm performance. The findings show there is a positive, although weak in a statistical sense, relationship between the two proxies for ESG performance and ROA in the fixed-effects baseline model and the alternative measures and conditional distributions of profitability; however, the relationship did not remain stable. In addition, the empirical results show there is no evidence to support that GTID plays an intervening role in the relationship between ESG performance and firm

performance. As such, the results suggest that Green Technology Innovation Disclosure has little to do with the productive economic application of green innovation technology in Indonesian energy and industrial firms during the period of 2021–2024. For managers and investors, the results suggest that disclosure of sustainability-oriented technology of green innovation would be of little use in providing information about whether the effort has been followed by quantitative realized financial results.

6. Conclusion

This study examines the association between ESG performance and firm performance and investigates whether Green Technology Innovation Disclosure (GTID) serves as a mediating mechanism among Indonesian energy and industrial firms during 2021–2024. The findings provide weak evidence of a positive association between ESG performance and firm performance, as the ESG coefficient is positive in the baseline fixed-effects model using ROA but statistically significant only at the 10 percent level and is not consistently supported when alternative performance measures and specifications are considered, indicating that the ESG-financial performance relationship is modest and sensitive to model specification. Furthermore, the results do not provide statistically significant evidence that GTID mediates this relationship, as neither the ESG–GTID path nor the GTID–firm performance path is statistically significant, and the bootstrapped indirect effect is not statistically different from zero.

These findings underpin the conceptual distinction between Green Technology Innovation Disclosure and the substantive implementation of green technological innovation, since greater disclosure of green technology-related activities does not necessarily reflect the scale, quality, operational effectiveness, or economic returns of actual technological investments. The results therefore offer limited support for the stakeholder-based expectation that stronger ESG performance is associated with improved financial performance and do not empirically support the proposed GTID signaling channel, without implying that signaling theory or actual green technological innovation is economically irrelevant. Comprehensively, the study suggests that managers, investors, and other stakeholders should interpret disclosure-based measures of green technological innovation cautiously and distinguish corporate reporting of green technological initiatives from their substantive implementation and realized economic outcomes when assessing the financial implications of corporate sustainability strategies.

Limitations and Future Research Directions

This study has several limitations that define the scope within which the findings should be interpreted. First, the relatively short 2021–2024 observation period may not fully capture the long-term or lagged financial effects of ESG performance and green technology-related activities, suggesting that future studies should extend the timeline and explicitly include model lagged ESG and innovation variables.

Second, the study employs Green Technology Innovation Disclosure (GTID) rather than actual green technological innovation, meaning that the insignificant mediation result should be limitedly interpreted as a lack of empirical support for the disclosure-based pathway, not as evidence that substantive green innovation does not support financial relevance; future research should therefore incorporate more direct indicators, such as green patents, environmental R&D expenditure, green capital expenditure, cleaner-production investment, or other observable measures of technological implementation.

Third, the ESG–firm performance relationship is sensitive to alternative measures and model specifications, indicating the need to examine additional accounting and market-based performance indicators, including Tobin's Q, market-to-book ratio, stock returns, and other profitability measures. Fourth, the use of a balanced panel of 82 Indonesian energy and industrial firms may limit generalizability and may introduce reporting-related sample selection because firms without consistent sustainability reporting are excluded; broader cross-sectoral and sector-specific analyses are therefore encouraged.

Fifth, the relatively low within-firm explanatory power of the GTID model suggests that changes in green technology-related disclosure may also be driven by other time-varying factors, such as regulatory pressure, reporting strategies, stakeholder scrutiny, environmental incidents, and technological investment decisions, which should, completely or partially, be incorporated in future models.

Sixth, the study relies on an observational fixed-effects panel design, thus the estimated relationships should be interpreted as associations rather than causal effects, as reverse causality, time-varying omitted variables, and measurement error may remain; future research could strengthen causal identification through dynamic panel estimators, instrumental-variable approaches, natural experiments, or regulatory shocks.

Taken together, future studies are encouraged to employ longer observation periods, more substantive measures of green technological innovation, broader performance indicators and industry coverage, richer determinants of GTID, and stronger causal identification strategies to provide a more comprehensive understanding of the relationships among ESG performance, green technology-related activities, and firm financial performance.

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