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Moderating Role Of Good Governance in the Relationship Between Carbon Emission Disclosure, Green Innovation, Eco-Efficiency, ESG, and Firm Value in Energy Sector

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ABSTRACT

This study examines the effect of carbon emission disclosure, green innovation, eco-efficiency, and environmental, social, and governance (ESG) on firm value, with good corporate governance as a moderating variable, in energy sector companies listed on the Indonesia Stock Exchange during the 2021–2024 period. A quantitative approach was employed using secondary data derived from annual and sustainability reports. The sample was selected through purposive sampling, resulting in 108 firm-year observations after outlier removal. Data were analyzed using panel data regression and Moderated Regression Analysis (MRA), preceded by model selection and classical assumption tests. Firm value was measured using Tobin's Q, while carbon emission disclosure, green innovation, eco-efficiency, and ESG were proxied using respective sustainability indicators. Good corporate governance was measured by institutional ownership. The partial test results indicate that carbon emission disclosure has a positive and significant effect on firm value ($p < 0.01$). In contrast, green innovation has a negative and significant effect ($p < 0.01$), and ESG also shows a negative and significant effect ($p < 0.05$), while eco-efficiency does not have a significant effect ($p > 0.05$). The model explains 7.6% of the variation in firm value ($R^2 = 0.076$). These findings suggest that sustainability practices do not uniformly enhance firm value, particularly in the short term, and highlight the importance of governance quality in strengthening sustainability strategies in emerging markets..

Keywords: Carbon emission disclosure, eco-efficiency, firm value, green innovation, good corporate governance.

INTRODUCTION

Greenhouse gas emissions such as CO_2, CH_4, N_2O, and CFCs are major drivers of global climate change (Djausal et al., 2023; Agustia et al., 2020). Rising global temperatures indicate insufficient mitigation efforts, intensifying the urgency for sustainable development and making carbon emission control a key priority (Shukla et al., 2022). Although the Paris Agreement (2015) set a global target to limit temperature increases below 2°C, global emissions remain volatile. Between 2021 and 2022, CO_2 emissions varied by 2.1%–8.1% (UN Climate Change, 2023b; World Economic Forum, 2023), indicating a gap in emission management between developed and developing countries and hindering net-zero targets (Ritchie and Roser, 2023). As a developing country, Indonesia faces growing energy demand and strong dependence on fossil fuels as the main emission sources (Pelawi and Inawati, 2024). In 2024, Indonesia recorded a 5% increase in carbon emissions and ranked sixth among the world's largest emitters (Crippa et al., 2024). The energy

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industry plays a vital role in the economy but is also a major emission source, with fossil fuels accounting for about 90% of the energy mix (Sunarto et al., 2024; Nugroho et al., 2023; Ritchie and Roser, 2023). For investors, sustainability disclosure is increasingly important, with over 70% considering ESG in decisions (World Economic Forum, 2023; Agustia et al., 2020). Energy companies that disclose sustainability information are more likely to gain legitimacy, improve investor perception, and contribute to higher firm value (Asyari and Hernawati, 2023; Permatasari, 2023).

Firm value reflects market perceptions of a company's growth prospects, financial stability, and long-term performance (Apriliani et al., 2024). It is shaped not only by financial performance but also by sustainability practices. Carbon emission disclosure, green innovation, eco-efficiency, and ESG are increasingly viewed as strategic tools to gain stakeholder support and enhance corporate reputation (Samhadi et al., 2024; Liu, 2023; Li et al., 2020). Carbon emission disclosure reflects transparency in emissions and mitigation strategies (Sunarto, 2024). Green innovation refers to the development of cleaner and more efficient technologies (Dewi and Rahmanianingsih, 2020). Eco-efficiency focuses on minimizing costs and environmental impact through resource efficiency (Amalo and Husen, 2024). ESG is a framework for evaluating environmental, social, and governance performance (Dwipa et al., 2024). This study is grounded in several theoretical perspectives. Legitimacy theory (Dowling and Pfeffer, 1975) explains that companies align their activities with societal norms to maintain legitimacy. Stakeholder theory (Freeman, 1984) emphasizes that firms must address stakeholder interests, not solely profitability, reflecting broader corporate accountability (Samhadi et al., 2024; Damas et al., 2021). Signalling theory (Spence, 1973) suggests that carbon emission disclosure, green innovation, eco-efficiency, and ESG send positive signals regarding a firm's commitment to sustainability, reducing investor uncertainty. Meanwhile, agency theory (Jensen and Meckling, 1976) highlights conflicts arising from information asymmetry between managers and investors. These practices help mitigate such gaps, strengthen investor trust, and ultimately enhance firm value (Yuliandhari et al., 2023).

Prior studies report mixed findings on the relationship between sustainability practices and firm value. Carbon emission disclosure is found to have a significant effect on firm value (Damanik and Prihandini, 2025; Fitri, 2024; Damas et al., 2021), while other studies report no effect (Sufiati and Taqwa, 2025; Pelawati and Inawati, 2024). Similarly, green innovation is shown to significantly affect firm value (Akib et al., 2025), although some studies find no effect (Fernindhia and Susilawati, 2026; Rahelliamelinda and Handoko, 2024). Eco-efficiency is also found to significantly influence firm value (Pelawi and Inawati, 2024), while other evidence suggests no effect (Adrizky et al., 2025; Anggarista et al., 2024). Finally, ESG is generally associated with firm value (Rafael and Lastanti, 2025; Samhadi et al., 2024), although some studies report insignificant results (Afdhal and Andayani, 2024). These inconsistencies may stem from differences in methods, samples, and models, as well as the limited examination of governance mechanisms, particularly good corporate governance, as a moderating variable in explaining the relationship between sustainability practices and firm value. In addition, prior studies are largely concentrated in developed economies, while evidence from developing countries, particularly Indonesia, remains limited despite differences in institutional structures, regulatory environments, and sustainability implementation that may influence firm value. These gaps indicate the need to examine whether good corporate governance, proxied by institutional ownership, can strengthen the relationship between carbon emission disclosure, green innovation, eco-efficiency, ESG, and firm value within the context of an emerging market. Therefore, this study addresses these empirical, conceptual, and contextual gaps by incorporating updated models and measurements and covering the 2021–2024 period, aligned with regulations.

LITERATURE STUDIES

Legitimacy Theory

Legitimacy theory (Dowling and Pfeffer, 1975), explains that energy companies seek to maintain operational continuity by aligning business activities with social norms and expectations. Reporting sustainability practices through carbon emission disclosure, green innovation, eco-efficiency, and ESG can therefore serve as a mechanism to obtain and sustain social legitimacy

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(Rahelliamelinda and Handoko, 2024; Dai dan Xue, 2022; Damas et al., 2021).

Stakeholder Theory

Stakeholder theory (Freeman, 1984), emphasizes that energy companies must consider and respond to the interests of all stakeholders in strategic decision making. This reflects corporate accountability to stakeholder expectations: companies should not focus solely on profitability, but also contribute to environmental sustainability (Samhadi et al., 2024; and Damas et al., 2021).

Signalling Theory

Signalling theory (Spence, 1973), suggests that carbon emission disclosure, green innovation, eco-efficiency, and ESG can send a positive signal to investors about an energy company's commitment to environmental and social responsibility. These signals can reduce investor uncertainty, strengthen corporate reputation, and ultimately increase firm value (Yuliandhari et al., 2023; and Rachmawati, 2021).

Agency Theory

Agency theory (Jensen and Meckling, 1976), in contrast, highlights potential conflicts of interest between managers and investors due to information asymmetry. As a result, these practices not only narrow information gaps but also reinforce investor trust, which is reflected in higher firm value (Yuliandhari et al., 2023).

Taken together, legitimacy theory, stakeholder theory, signalling theory, and agency theory complement one another in explaining the relationship between sustainability practices and firm value. Legitimacy theory explains how sustainability practices help firms gain and maintain social acceptance, stakeholder theory emphasizes the fulfillment of stakeholder expectations through responsible corporate behavior, signalling theory explains how such practices convey positive information to investors, while agency theory highlights their role in reducing information asymmetry and agency conflicts. Collectively, these four theories provide an integrated theoretical foundation that explains how sustainability practices can enhance firm value through social legitimacy, stakeholder support, positive market signals, and improved governance mechanisms.

Research Conceptual Framework

Overall, the relationships among the study variables are summarized in Figure 2, which presents the theoretical framework of the research model:

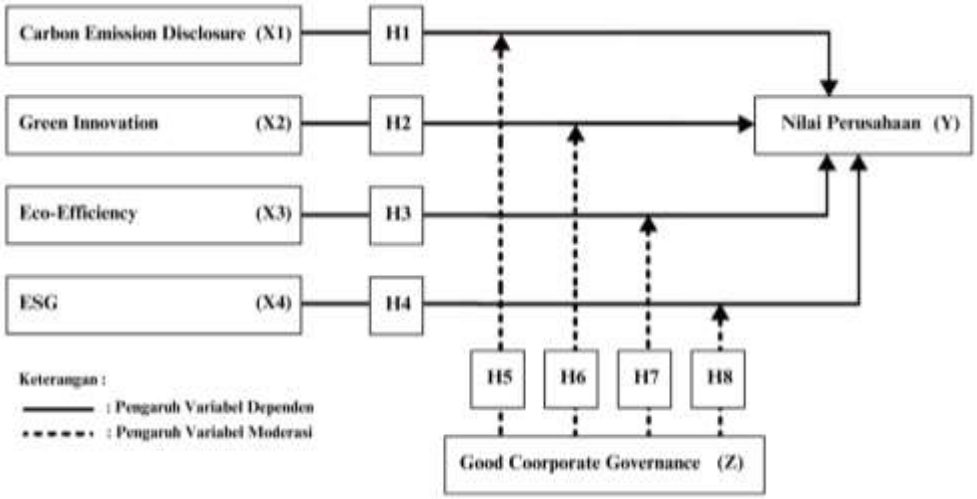

Figure 2. Research conceptual framework
Source: Data processed by researchers (2026).

The Effect Carbon Emission Disclosure On Firm Value

Carbon emission disclosure reflects an energy company's responsibility to manage and report environmental impacts particularly operational carbon emissions in a transparent and accountable manner (Velte et al., 2020). Under signalling theory (Spence, 1973), comprehensive sustainability

disclosure can serve as a credible signal to investors, strengthening confidence in a firm's long term sustainability prospects (Houten and Wedari, 2023; Alfayerds and Setiawan, 2021). Empirical evidence supports this argument Fitri, (2024), Adrizky et al., (2025), and Artika et al., (2025), report a significant association between carbon emission disclosure and firm value. Greater disclosure may therefore enhance investors' perceptions of sustainability oriented competitiveness and, in turn, increase firm value. Accordingly, the following hypothesis is proposed:
H1: Carbon emission disclosure positively affects firm value.

The Effect Green Innovation On Firm Value

Green innovation represents a sustainability strategy in energy firms that focuses on developing cleaner technologies, products, and production processes to reduce carbon emissions, improve energy efficiency, and minimize operational waste amid global decarbonization pressures. From a signalling perspective (Spence, 1973), green innovation may communicate a firm's long term commitment to efficiency, environmental risk management, and competitiveness during the transition to clean energy (Fitri, 2024). Consistent with this view, Akib et al. (2025), Fitri (2024), and Damas et al. (2021), find that green innovation significantly affects firm value. Green innovation can strengthen investor trust and corporate reputation and may also support firm value by lowering future energy costs and regulatory risks, thereby improving expected cash flows and financial stability. Thus, the second hypothesis is formulated as follows:
H2: Green innovation positively affects firm value.

The Effect Eco-Efficiency On Firm Value

Eco-efficiency refers to a managerial approach that seeks to create economic value by using resources more efficiently while reducing environmental impacts (Amalo and Husen, 2024). In line with stakeholder theory (Freeman, 1984), eco-efficiency signals responsiveness to stakeholder expectations by combining environmental responsibility with operational performance improvement. Supporting this argument, Damanik and Prihandini (2025), Fitri (2024), and Damas et al., (2021), document a significant effect of eco-efficiency on firm value. By reducing production costs and improving profit margins, eco-efficiency may enhance investor perceptions and increase firm value. The third hypothesis is therefore proposed:
H3: Eco-efficiency positively affects firm value.

The Effect ESG On Firm Value

Environmental, Social, and Governance (ESG) performance reflects a firm's ability to manage environmental, social, and governance risks in an integrated manner as part of its sustainability performance (Dwipa et al., 2024). From the stakeholder perspective (Freeman, 1984), ESG implementation represents corporate accountability to a broader set of stakeholders. From a signalling perspective (Spence, 1973), strong ESG performance can function as a credibility signal indicating long term commitment to sustainable business practices. Empirically, Rafael and Lastanti (2025), Samhadi et al., (2024), and Wu and Li (2023), report that ESG significantly affects firm value, suggesting that ESG can strengthen investor confidence, reduce perceived risk, and enhance corporate reputation. Accordingly, the fourth hypothesis is stated as follows:
H4: ESG positively affects firm value.

Good Corporate Governance Moderating On The Relationship Between Carbon Emission Disclosure And Firm Value

Good corporate governance is expected to shape how sustainability practices are translated into firm value. Drawing on agency theory (Jensen and Meckling, 1976),stronger governance can reduce agency conflicts through effective oversight and monitoring, thereby improving the quality and credibility of corporate disclosures including carbon emission disclosure and reinforcing investor trust (Fitri, 2024). Research conducted by Fitri (2024), further reports that good corporate governance moderates the relationship between carbon emission disclosure and firm value, implying that the impact of disclosure may be stronger when governance mechanisms are more robust. The following hypothesis is therefore proposed:

H5: Good corporate governance moderates the relationship between carbon emission disclosure and firm value.

Good Corporate Governance Moderating On The Relationship Between Green Innovation And Firm Value

From the stakeholder perspective (Freeman, 1984), governance mechanisms also reflect a firm's responsibility to stakeholders in managing environmental impacts, including ensuring that green innovation is implemented effectively and efficiently with a long term orientation Samhadi et al., (2024). Prior studies indicate that governance may strengthen the value relevance of green innovation. Research conducted by Fitri (2024) and Samhadi et al., (2024), find that good corporate governance moderates the relationship between green innovation and firm value, suggesting that investors are more likely to value green innovation when it is managed professionally and accountably. Thus, the sixth hypothesis is formulated as follows:

H6: Good corporate governance moderates the relationship between green innovation and firm value.

Good Corporate Governance Moderating On The Relationship Between Eco-Efficiency And Firm Value

Agency theory (Jensen and Meckling, 1976), also suggests that governance can ensure that efficiency policies are implemented substantively rather than symbolically, requiring consistent managerial commitment to resource management and cost control. Fitri (2024), finds that good corporate governance moderates the relationship between eco-efficiency and firm value, indicating that effective oversight may strengthen investor confidence in management quality and increase the value implications of eco-efficiency. Therefore, the seventh hypothesis is proposed:

H7: Good corporate governance moderates the relationship between eco-efficiency and firm value.

Good Corporate Governance Moderating On The Relationship Between ESG And Firm Value

Finally, combining stakeholder theory (Freeman, 1984) and agency theory (Jensen and Meckling, 1976), good corporate governance may enhance transparency, accountability, and strategic decision making in ESG implementation. Empirical evidence supports this moderating role Samhadi et al., (2024), and Wu and Li (2023), report that governance moderates the relationship between ESG and firm value. This suggests that investors may view ESG as more credible and value-relevant when it is embedded within strong governance structures. Hence, the eighth hypothesis is stated as follows:

H8: Good corporate governance moderates the relationship between ESG and firm value.

RESEARCH METHOD

This section describes the research procedures in detail, including the research design, population and sampling technique, data type and sources, research variables, and analytical approach. This study adopts an explanatory research design with a quantitative approach. The population consists of all energy sector companies listed on the Indonesia Stock Exchange (IDX/BEI) during the 2021–2024 period. The sample was selected using purposive sampling based on the following criteria:

1. Energy sector companies that were listed on the Indonesia Stock Exchange (IDX/BEI) throughout 2021–2024.
2. Energy sector companies that published audited annual reports and sustainability reports for the 2021–2024 period, accessible through the official IDX/BEI website and the respective companies' official websites.

The study uses quantitative panel data. The data are secondary and were obtained from the annual reports and sustainability reports of energy-sector companies for 2021–2024. In this study, carbon-emission disclosure, green innovation, eco-efficiency, and ESG are treated as independent variables (X). Firm value is the dependent variable (Y), while good corporate governance is included as the moderating variable. Detailed operational definitions of the variables are presented in Table 1:

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Table 1. Operational Definition of Research Variables

Variable	Proxy
Firm Value (Y)	$\text{Tobins'Q} = \frac{\text{Market capitalization} + \text{Total liabilities}}{\text{Total assets}}$ Captures the market's assessment of a firm's ability to manage resources and generate sustainable profits, reflected in higher firm value. (Dewi and Narayana, 2020).
Carbon Emission Disclosure (X1)	$\text{CED} = \frac{\text{Number of items diclosure}}{\text{Total disclosure items}} \times 100\%$ Measures the extent to which the company discloses information related to carbon emissions from operational activities, signaling accountability, strengthening investor trust, and potentially enhancing competitive advantage and firm value. (Blesia et al., 2023; Kurnia et al., 2021; Choi et al., 2013).
Green Innovation (X2)	$\text{GI} = \frac{\text{Number of items diclosure}}{\text{Total disclosure items}}$ Measures the extent of environmentally friendly technologies, systems, practices, and production processes implemented by the firm to improve energy efficiency, reduce carbon emissions, and strengthen reputation among the public and investors through commitment to environmental sustainability. (Dewi and Rahmianingsih, 2020).
Eco-Efficiency (X3)	$\text{Eco-efficiency} = \frac{\text{Value of product}}{\text{Enviromental influence}}$ Assesses how effectively the firm creates economic value while improving environmental performance by reducing environmental impacts associated with operational activities. (Damas et al., 2021).
ESG (X4)	$\text{ESG} = \frac{\text{Number of items diclosure}}{\text{Total disclosure items}} \times 100\%$ Measures the firm's environmental, social, and governance practices as reflected in disclosure of operational impacts, indicating sustainability performance intended to support long-term financial value creation. (Dwipa et al., 2024).
Good Corporate Governance (Z)	$\text{KI} = \frac{\text{Share owned by institutional investors}}{\text{Total outstanding shares}} \times 100\%$ Represents the proportion of shares held by institutional investors, who typically play a monitoring role by overseeing management and encouraging more transparent and accountable corporate governance. (Samhadi et al., 2024).

Source: Data processed by researchers (2026).

Panel data regression was employed to analyze the study data. Because the model includes a moderating variable, the analysis was conducted using Moderated Regression Analysis (MRA) within a panel data framework. All statistical tests were performed using STATA. The empirical model is specified as follows:

$$Y_{it} = \alpha + \beta_{it} X^1_{it} + \beta_{it} X^2_{it} + \beta_{it} X^3_{it} + \beta_{it} X^4_{it} + \beta_{it} X^1_{it} Z_{it} + \beta_{it} X^2_{it} Z_{it} + \beta_{it} X^3_{it} Z_{it} + \beta_{it} X^4_{it} Z_{it} + \varepsilon_{it}$$

Where:
Y : Firm value (Tobin's Q)
X^1 : Carbon emission disclosure
X^2 : Green Innovation

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X^3 : Eco-Efficiency
X^4 : ESG
Z : Good corporate governance
α : Constant term
β : Regression coefficients
ε : Error term
i : Cross-sectional
t : Time series

The data analysis procedures included descriptive statistics, estimation and selection of the appropriate panel regression model, classical assumption tests, panel regression analysis, hypothesis testing, and panel moderated regression analysis.

RESULTS

This study uses secondary data from energy sector companies listed on the Indonesia Stock Exchange (IDX/BEI), observed over a four year period (2021–2024). Table 2 presents the sampling procedure and the resulting sample selection:

Table 2. Description of the Research Sample Energy Sector Companies (2021-2024)

Description	Total
Energy sector companies listed on the Indonesia Stock Exchange (IDX/BEI), 2021–2024	89
Less companies that did not publish annual reports and sustainability reports during the study period (2021–2024)	(47)
Energy sector companies with published annual reports and sustainability reports (2021–2024)	42
Total firm year observations	168
Less outlier observations	(60)
Final observations after outlier removal	108

Source: Data processed by researchers (2026).

Descriptive Statistic Test

Table 3. Descriptive Statistics of Research Variables

Variable	N	Mean	Std.Dev	Minimum	Maximum
Firm Value	108	1.138	0.626	0.526	3.863
Carbon Emission Disclosure	108	0.825	0.087	0.611	0.944
Green Innovation	108	0.791	0.136	0.444	1
Eco-Efficiency	108	0.746	0.143	0.666	1
ESG	108	0.836	0.080	0.709	0.986
Good Corporate Governance	108	0.678	0.229	0.156	0.927

Source: Data processed by STATA (2026).

The descriptive statistics show that firm value, proxied by Tobin's Q, has a mean of 1.138 and a standard deviation of 0.626. Because the standard deviation is lower than the mean, the variation in firm value across the sample can be considered relatively moderate. The sustainability-related variables carbon-emission disclosure, green innovation, eco-efficiency, and ESG each have mean values above 0.70 with standard deviations that are comparatively small relative to their means. This indicates generally high levels of sustainability disclosure/practices among the sampled firms and relatively homogeneous data patterns. Meanwhile, good corporate governance (the moderating variable) has a mean of 0.678 and a standard deviation of 0.229, suggesting that governance practices in the energy sector are implemented with a moderate degree of variation across firms.

Classic Assumption Test

Normality Test

Table 4. Normality Test Results

Variable	N	Skewness	Kurtosis	Prob>Chi^2	Description
Firm Value	108	0.0000	0.0000	0.0000	Not Normal

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Carbon Emission Disclosure	108	0.0239	0.2314	0.0454	Not Normal
Green Innovation	108	0.0434	0.0215	0.0155	Not Normal
Eco-Efficiency	108	0.0000	0.2083	0.0002	Not Normal
ESG	108	0.7434	0.0000	0.0000	Not Normal
Good Corporate Governance	108	0.0002	0.4625	0.0026	Not Normal

Source: Data processed by STATA (2026).

The normality test results show that all variables have Prob > Chi² values below 0.05**,** indicating that the data are not normally distributed**.** This non normality likely reflects heterogeneity across energy-sector firms during the 2021–2024 period. Firm value proxied by Tobin's Q exhibits a not normal distribution, which may be driven by differences in market capitalization and investor perceptions across firms, as well as stock price volatility influenced by global energy price dynamics and the ongoing energy transition process. Carbon emission disclosure is also non-normally, potentially due to variation in compliance and transparency levels among firms in applying sustainability reporting standards, resulting in asymmetric disclosure patterns. Green innovation shows non-normality because implementation remains uneven some firms have adopted green innovation intensively as part of their sustainability strategy, while others are still at an early stage.

Similarly, eco-efficiency may be non-normally distributed due to differences in production technology, firm scale, and cost structure across companies firms with more advanced technologies and stronger environmental management systems tend to achieve higher eco-efficiency than more conventional firms. ESG values may be non-normal because sustainability practices are implemented unevenly across the sector, particularly between large and small firms. Finally, good corporate governance proxied by institutional ownership also departs from normality, which can be attributed to differences in ownership structures across energy sector companies.

Multicollinearity Test

Table 5. Multicollinearity Test Results

Variable	VIF	1/VIF	Description
Eco-Efficiency	1.69	0.591336	No Multicollinearity
Carbon Emission Disclosure	1.52	0.657483	No Multicollinearity
ESG	1.27	0.789112	No Multicollinearity
Green Innovation	1.24	0.809713	No Multicollinearity
Good Corporate Governance	1.22	0.818945	No Multicollinearity
Mean VIF	**1.39**		

Source: Data processed by STATA (2026).

The multicollinearity test results indicate that all variables in the study have Variance Inflation Factor (VIF) values below 10 and tolerance values (1/VIF) above 0.10. The highest VIF is observed for eco-efficiency (1.69), while the lowest is for good corporate governance (1.22), with an average VIF of 1.39. These values suggest that there is no evidence of multicollinearity among the independent variables, nor between the independent variables and the moderating variable. Therefore, the model satisfies the assumption of no multicollinearity, and all variables can be included simultaneously in the panel regression and MRA analyses.

Heteroscedasticity Test

Table 6. Heteroscedasticity Test Results

Statistic	Value	Description
Prob>Chi^2	0.2152	No Heterocedasticity
Sig.	0.05	

Source: Data processed by STATA (2026).

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The heteroscedasticity test produces a Prob > Chi² value of 0.2152, which exceeds the 0.05 significance level. This indicates that the panel regression model does not suffer from heteroscedasticity. Accordingly, the homoskedasticity assumption is satisfied, and the coefficient estimates can be considered appropriate and reliable for subsequent analyses.

Autocorrelation Test

Table 7. Autocorrelation Test Results

Statistic	Value	Description
Prob>Chi²	0.0000	Autocorrelation Detected
Sig.	0.05	Observed

Source: Data processed by STATA (2026).

The autocorrelation test yielded a Prob > Chi² value of 0.0000, which is below the significance threshold of 0.05 therefore, the null hypothesis is rejected. Thus, it can be concluded that there is autocorrelation in the initial estimation model, namely the Random Effects Model (REM). To address this issue, this study re-specified the model using the Common Effect Model (CEM) approach within a panel data framework. The results of the re-estimation using the CEM model show that the Durbin–Watson value is 2.324 at a significance level of 0.05 or 5%, with a sample size of 108 and 4 independent variables, yielding a dl value of 1.610 and a du value of 1.763. Since the Durbin–Watson statistic is greater than 4 – du (2.324 > 2.237), it can be concluded that there is no significant autocorrelation in the regression model. Thus, the regression model used satisfies the classical assumptions and is suitable for hypothesis testing. Based on these results, the use of the Common Effect Model (CEM) in this study is considered an appropriate approach, not only because of its suitability for panel data characteristics, but also because of its ability to produce models that are more stable, efficient, and satisfy the basic assumptions of regression.

Panel Regression Model Selection

Chow Test

The Chow test is used to determine whether the common effects model (CEM) or the fixed effects model (FEM) is more appropriate. The test result shows Prob > F = 0.0000, which is below 0.05. This indicates significant firm specific heterogeneity, meaning that the fixed effects model (FEM) is preferred over the common effects model.

Lagrange Multiplier (LM) Test

The Lagrange Multiplier (LM) test is employed to compare the common effects model (CEM) with the random effects model (REM). The LM result reports Prob > Chi² = 0.0000, which is below 0.05, indicating significant cross-sectional (firm level) effects. Therefore, the random effects model (REM) is preferred to the common effects model.

Hausman Test

The Hausman test is used to determine whether the fixed effects model (FEM) or the random effects model (REM) provides the more appropriate specification. The test result shows Prob > Chi-bar² = 0.8858, which exceeds 0.05. This suggests that the firm specific effects are not systematically correlated with the regressors. Hence, the random effects model (REM) is considered more efficient and is selected as the final panel regression model for this study.

Table 8. Random Effect Model Estimation

Prob>Chi²				0.0000
R-Squared				0.0760
Variable	**Coefficient**	**Std.Dev**	**z**	**P>|z|**
CED	1.558	0.311	5.01	0.000
GI	-0.637	0.197	-3.24	0.001
Eco	-0.111	0.143	-0.78	0.435
ESG	-0.592	0.278	-2.13	0.033

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GCG	0.220	0.239	0.92	0.356
Cons	0.786	0.410	1.92	0.055

Source: Data processed by STATA (2026).

Hypothesis Testing

Coefficient of Determination (R^2) Test

The coefficient of determination indicates an R-squared value of 0.0760 based on 108 firm year observations. This suggests that approximately 7.6% of the variation in firm value among energy sector firms is explained by the independent variables and the moderating variable included in the model, while the remaining 92.4% is attributable to other factors outside the model. Although the explanatory power is relatively modest, it is still considered acceptable in firm level panel research, where firm value is often influenced by a wide range of unobserved and external determinants. After re-specifying the model using the Common Effect Model (CEM), the coefficient of determination increased to an R-Square value of 0.1268, indicating that the independent and moderating variables in the model account for 12.68% of the variation in firm value. The increase from the previous value of 0.0760 to 0.1268 indicates an improvement in the model's ability to capture the relationship between the independent and dependent variables. This 5.08% increase reflects that re-specifying the model using the CEM approach provides a more accurate estimation structure, allowing for a better explanation of firm value variation compared to the previous model. This indicates that the adjusted model has a higher goodness of fit and is better able to represent the empirical relationships among the variables.

Simultaneous Test (F)

The joint significance test reports Prob > Chi² = 0.000, which is below the 0.05 significance level. This result indicates that the independent variables and the moderating variable are jointly significant in explaining firm value. Therefore, the panel regression model is deemed statistically adequate and suitable for subsequent hypothesis testing.

Partial Test (T-Test)

Table 9. Partial Test Results (T-Test)

Variable	Hypothesis	Coefficient	Std.Dev	z	P>|z|	Description
CED	H1	1.558	0.311	5.01	0.000	Accepted
GI	H2	-0.637	0.197	-3.24	0.001	Rejected
Eco	H3	-0.111	0.143	-0.78	0.435	Rejected
ESG	H4	-0.592	0.278	-2.13	0.033	Rejected
Independent Variable: Firm Value						

Source: Data processed by STATA (2026).

The partial (T) test results indicate that carbon emission disclosure variable has a coefficient value of 1.558 with a p-value of 0.000 < 0.05, thus H1 is accepted, indicating that carbon emission disclosure has a positive and significant effect on company value. The green innovation variable has a coefficient value of -0.637 with a p-value of 0.001 < 0.05, so H2 is accepted, indicating that green innovation has a negative and significant effect on company value. The eco-efficiency variable has a coefficient value of -0.111 with a p-value of 0.435 > 0.05, so H3 is rejected, indicating that eco-efficiency does not have a significant effect on company value. Meanwhile, the ESG variable has a coefficient value of -0.592 with a p-value of 0.033 < 0.05, so H4 is accepted, indicating that ESG has a negative and significant effect on company value.

Moderation Test Results (MRA)

Table 10. Moderating Test Results (MRA)

Variable	Hypothesis	Coefficient	Std.Dev	z	P>|z|	Description
CED*GCG	H5	1.508	3.068	0.49	0.624	Rejected
GI*GCG	H6	-4.226	2.076	-2.04	0.045	Accepted
Eco*GCG	H7	5.192	2.546	2.04	0.044	Accepted
ESG *GCG	H8	10.277	3.921	2.62	0.010	Accepted
Independent Variable: Firm Value						

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Moderator Variable: Good Corporate Governance
Source: Data processed by STATA (2026).

The results of the MRA test analysis show that the interaction between the carbon emission disclosure and good corporate governance variables has a coefficient value of 1.508 with a p-value of 0.624 > 0.05, so H5 is rejected, indicating that good corporate governance is unable to moderate the effect of carbon emission disclosure on company value. Furthermore, the interaction between the green innovation and good corporate governance variables has a coefficient value of -4.226 with a p-value of 0.045 < 0.05, so H6 is accepted, indicating that good corporate governance is able to significantly moderate and weaken the effect of green innovation on company value. The interaction between the eco-efficiency and good corporate governance variables has a coefficient value of 5.192 with a p-value of 0.444 < 0.05, so H7 is accepted, indicating that good corporate governance can moderate the influence of eco-efficiency on company value. Meanwhile, the interaction between ESG and good corporate governance variables has a coefficient value of 10.277 with a p-value of 0.010 < 0.05, so H8 is accepted, indicating that good corporate governance can moderate and strengthen the influence of ESG on company value.

DISCUSSIONS

The Effect Carbon Emission Disclosure On Firm Value

The findings indicate that carbon emission disclosure has a positive and statistically significant effect on firm value. In practice, carbon emission disclosure reflects the company's efforts to plan and report emission reduction initiatives, including tracking and comparing annual carbon emission levels generated through operational activities, which may reduce investor hesitation toward investing in energy sector firms (Fitri, 2024). This suggests that more extensive disclosure attracts investor attention the more management discloses information regarding environmental responsibility particularly carbon emission disclosure the higher the firm value tends to be. This result is consistent with signalling theory (Spence, 1973), which posits that voluntary and transparent disclosure can serve as a positive signal to investors. By openly communicating emission levels and mitigation efforts, firms signal awareness of environmental impacts and commitment to climate change mitigation. Investors may interpret such disclosure as evidence of credible long term commitment to reducing environmental harm, which strengthens investor trust, enhances corporate reputation, and ultimately contributes to higher firm value.

Empirically, this finding aligns with studies reporting that carbon emission disclosure significantly affects firm value (Adrizky et al., 2025; Artika et al., 2025; Damanik and Prihandini , 2025; Anggarista et al., 2025; Huang et al., 2025; Rahmawati et al., 2025; Putri and Paramita, 2025; Fitri, 2024; Fitriana et al., 2024; Samhadi et al., 2024; Zaikin et al., 2024; Blesia et al., (2023); Yuliandhari et al., (2023); Le dan Cho (2021); Damas et al., 2021; Jiang et al., 2021; and Kurnia et al., 2021). However, it contrasts with research that finds no significant relationship between carbon emission disclosure and firm value (Sufiati and Taqwa, 2025; Dianti and Puspitasari, 2024; Gayatri and Yuniarta, 2024; Nashrulloh and Achyani, 2024; and Rachmawati, 2021). Overall, the present results suggest that carbon emission disclosure can increase firm value by strengthening investor confidence and supporting long term business sustainability in the energy sector.

The Effect Green Innovation On Firm Value

The results also show that green innovation has a negative and statistically significant effect on firm value, meaning that higher levels of green innovation are associated with a lower firm value in the sample. This pattern suggests that not all firms are equally capable of implementing green innovation, as environmentally friendly innovation often requires substantial upfront investment, intensive research and development (R&D), adoption of advanced green technologies, and more complex operational systems to reduce environmental damage from core activities. In the short term, these large expenditures can raise operating costs and compress profitability, which may weaken investor perceptions of financial performance and reduce firm value. In the Indonesian context, investors may be more sensitive to short term financial outcomes such as immediate

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earnings and cash flows than to long-term environmental benefits. As a result, green innovation may be perceived as a source of risk and uncertainty rather than an immediate competitive advantage, meaning that it is not yet fully valued by the market as a firm value creation strategy.

This negative relationship may also reflect investor behavior in emerging markets, where market participants tend to prioritize short term profitability, dividend expectations, and cash flow stability over long term sustainability gains. As a result, green innovation expenditures may be interpreted as cost burdens rather than strategic investments, creating a market mispricing in which sustainability initiatives are not yet fully capitalized into firm value. This finding also indicates a short term versus long term trade off, where the costs of green innovation are recognized immediately by the market, while its economic benefits tend to materialize gradually. In this context, investors may respond more strongly to short term earnings pressure than to future sustainability gains.

Although signalling theory (Spence, 1973), suggests that green innovation should send a positive signal about long term efficiency and environmental risk management (Fitri, 2024), the negative association observed here implies that the market may discount such signals when the short term cost burden is high. This finding is consistent with studies reporting significant effects of green innovation on firm value (Akib et al., 2025; Artika et al., 2025; Damanik and Prihandini, 2025; Nugroho and Dewi, 2025; Nurhalimah et al., 2025; Fitri, 2024; Fanda and Damayanti, 2024; Fitriana et al., 2024; Zaikin et al., 2024; Yuliandhari et al., 2023; Damas et al., 2021; and Dewi and Rahmianingsih, 2020). While it contrasts with research showing no significant relationship (Fernindhia and Susilawati, 2026; and Rahelliamelinda and Handoko, 2024.Importantly, this result does not diminish the strategic relevance of green innovation; rather, it indicates that its long term benefits may not yet be fully reflected in firm value, particularly among energy sector firms in Indonesia.

The Effect Eco-Efficiency On Firm Value

The findings indicate that eco-efficiency does not have a statistically significant effect on firm value. Stock price fluctuations may reflect investor uncertainty in assessing the economic benefits of eco-efficiency initiatives. In the energy sector, eco-efficiency tends to emphasize resource use efficiency and environmental impact reduction benefits that may not translate into immediate market valuation when investors remain primarily focused on short term profitability. Moreover, implementing eco-efficiency frequently requires substantial upfront investment in green technologies, process improvements, and compliance costs related to environmental regulations, which can compress earnings in the short run.

This result appears inconsistent with the normative expectation of stakeholder theory (Freeman, 1984), which suggests that responsible resource management should be valued by stakeholders. However, it is also consistent with stakeholder theory (Freeman, 1984) and legitimacy theory (Dowling and Pfeffer, 1975), which emphasize that eco-efficiency may function primarily to meet stakeholder expectations and maintain social legitimacy, rather than to increase firm value immediately especially when benefits materialize over a longer horizon. Empirically, this finding aligns with prior studies reporting that eco-efficiency does not significantly affect firm value (Adrizky et al., 2025; Fitriyani et al., 2025; Rafael and Lastanti , 2025; Anggarista et al., 2024; Sunarto et al., 2024; Rahelliamelinda and Handoko 2024; and Yuliandhari et al., 2023). In contrast, other studies report a significant effect (Damanik and Prihandini, 2025; Fitri 2024; Pelawi and Inawati, 2024; and Damas et al., 2021). Overall, the results suggest that eco-efficiency initiatives in the energy sector may not be directly reflected in firm value within the observation period.

The Effect ESG On Firm Value

The results further show that ESG has a negative and statistically significant effect on firm value. This implies that higher ESG scores are associated with lower firm value among energy sector firms in the sample. One possible explanation is that investors may perceive ESG implementation and disclosure as increasing short term costs, thereby weakening profitability, while not yet fully pricing in the long-term benefits of ESG adoption. This interpretation may be particularly relevant for the energy sector, which is capital intensive and high risk consequently,

investors may be more sensitive to expenditures viewed as non productive in the short term. From a theoretical perspective, this finding can still be interpreted within stakeholder theory (Freeman, 1984), which frames ESG as a form of accountability to a broad set of stakeholders. At the same time, signalling theory (Spence, 1973), suggests that strong ESG performance should act as a credibility signal of long term sustainability commitment. The negative association observed here suggests that, in this context, the cost implications may dominate the market's short run valuation. This negative relationship may also reflect investor behavior in emerging markets, where investors tend to prioritize short term profitability and may perceive ESG related expenditures as compliance costs rather than strategic value creating investments. As a result, the market may not fully price the long term benefits of ESG implementation, creating a potential market mispricing in firm valuation. This finding also indicates a short term versus long term trade off, where ESG adoption may impose immediate cost pressures in the short run, while its benefits in terms of risk reduction, reputation enhancement, and sustainable value creation are more likely to materialize over the long term. This result is consistent with studies reporting a significant relationship between ESG and firm value (Bachtiar et al., 2025; Rafael and Lastanti, 2025; Anggarista et al., 2024; Dwipa et al., 2024; Samhadi et al., 2024; Adlah and Febrianto (2023); and Wu and Li (2023). But contrasts with studies that find no significant effect Afdhal and Andayani, (2024). Overall, the findings indicate that ESG implementation has not yet translated into higher market valuation in the energy sector and may be perceived by investors as a short term burden.

Good Corporate Governance Moderating On The Relationship Between Carbon Emission Disclosure And Firm Value

The results indicate that good corporate governance does not significantly moderate the relationship between carbon emission disclosure and firm value. This suggests that governance mechanisms have not strengthened (or weakened) the value relevance of carbon emission disclosure in the sample. Although good corporate governance is expected to enhance the credibility of carbon related disclosures and thereby increase investor confidence, the findings imply that investors may not yet view carbon emission disclosure as a primary driver of valuation in the energy sector, particularly when short term profitability remains a dominant consideration. In the Indonesian context, carbon emission disclosure may still be perceived as largely compliance driven, particularly in relation to POJK No. 51/POJK.03/2017 on sustainability reporting obligations, rather than as substantive sustainability commitment.

This result contrasts with the expectation of agency theory (Jensen and Meckling, 1976), which argues that governance reduces information asymmetry and agency conflicts by improving disclosure quality. However, it is consistent with signalling theory (Spence, 1973), if the market does not interpret carbon emission disclosure as a sufficiently strong or credible signal even when governance practices are present. This finding aligns with studies reporting that carbon emission disclosure does not significantly affect firm value when moderated by governance Blesia et al., 2023, but contrasts with evidence suggesting a moderating role Fitri (2024). Overall, the results imply that, within the observation period, carbon emission disclosure may remain compliance oriented and may not provide incremental value to investors, even under stronger governance.

Good Corporate Governance Moderating On The Relationship Between Green Innovation And Firm Value

The results show that good corporate governance significantly moderates the relationship between green innovation and firm value. Interpreted through stakeholder theory (Freeman, 1984), strong governance can function as an internal control mechanism that ensures green innovation policies are implemented effectively and aligned with environmental principles, thereby strengthening stakeholder confidence and organizational accountability. With stronger governance, firms may be more capable of adopting green innovation in a structured and credible manner, improving operational sustainability and efficiency over time. Such governance may also reduce information asymmetry and increase the credibility of sustainability initiatives, making the firm more attractive to stakeholders and environmentally conscious investors. This result is consistent with studies reporting that governance moderates the green innovation firm value relationship (Fitri, 2024; Samhadi et al., 2024; Zaikin et al., 2024; and Dai and Xue, 2022). Overall, the findings

suggest that good corporate governance plays a key role in shaping the value implications of green innovation in the energy sector.

Good Corporate Governance Moderating On The Relationship Between Eco-Efficiency And Firm Value

The findings also indicate that good corporate governance significantly moderates the relationship between eco-efficiency and firm value. Eco-efficiency reflects the extent to which firms optimize resource use, reduce operating costs, and minimize environmental impacts, thereby balancing economic and environmental performance. Consistent with agency theory (Jensen and Meckling, 1976), good corporate governance can ensure that eco-efficiency initiatives are implemented substantively rather than symbolically, and that operational efficiency policies are aligned with shareholder value creation rather than mere compliance or image building. Strong governance can reduce agency costs and help convert resource savings and efficiency gains into value relevant outcomes. In addition, stakeholder theory (Freeman, 1984), suggests that governance supported eco-efficiency can strengthen relationships with investors, regulators, and communities, supporting legitimacy and sustained stakeholder backing that may contribute to firm value. This finding is consistent with Fitri (2024), indicating that governance enhances the value relevance of eco-efficiency. Overall, the results suggest that good corporate governance is important for ensuring that eco-efficiency functions not only as environmental impact mitigation but also as a credible value creation strategy in the energy sector.

Good Corporate Governance Moderating On The Relationship Between ESG And Firm Value

Finally, the results indicate that good corporate governance significantly strengthens the relationship between ESG and firm value. This suggests that the effectiveness of ESG implementation in supporting firm value in the energy sector depends heavily on governance quality. ESG is not merely a non-financial disclosure instrument it also represents a strategic approach to managing environmental, social, and governance risks risks that increasingly influence investor evaluation. In line with stakeholder theory (Freeman, 1984), governance strengthens ESG by improving transparency, accountability, and integration of ESG into strategic decision making, thereby increasing stakeholder trust and supporting firm value The result is also consistent with legitimacy theory (Dowling and Pfeffer, 1975) and signalling theory (Spence, 1973), ESG implemented under strong governance can demonstrate compliance, responsibility, and long term commitment to sustainability, reducing reputational risk and external pressures that might otherwise depress firm value. Moreover, ESG under robust governance serves as a stronger signal regarding management quality and long-term prospects, encouraging investor confidence and lowering perceived risk. This finding aligns with prior studies showing that governance moderates the ESG firm value relationship (Wu and Li, 2023 and Samhadi et al., 2024). Overall, the results indicate that good corporate governance not only strengthens the ESG firm value relationship but also serves as a foundational mechanism that enhances ESG effectiveness through transparency, accountability, and responsibility thereby enabling ESG to generate both economic value and broader social and environmental value.

CONCLUSION

This study contributes to the literature by showing that sustainability practices do not uniformly enhance firm value in the energy sector. A key scientific contribution is the finding that green innovation and ESG negatively affect firm value, while eco-efficiency has no significant effect, indicating a short-term cost versus long-term value trade-off in sustainability investments. This study also highlights good corporate governance as a boundary condition that strengthens the value implications of green innovation, eco-efficiency, and ESG, extending agency theory. This study has limitations related to the use of secondary data and a relatively short observation period (2021–2024). Future research is encouraged to use longer observation periods, include additional control variables, and extend the sample to other carbon-intensive industries.

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