The effect of carbon emission disclosure, eco-efficiency, and green innovation on corporate value with environmental performance as a moderating variable

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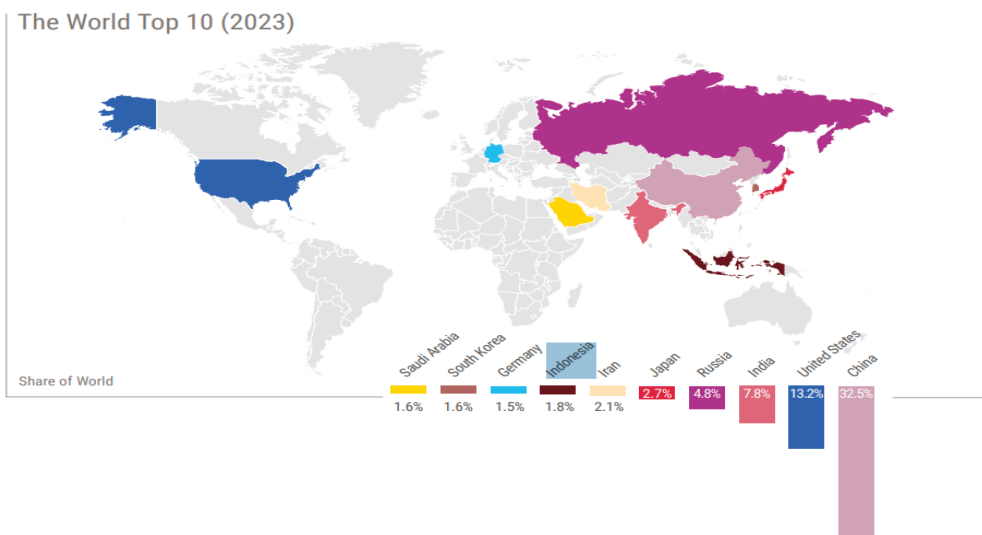*Corresponding Email addresses: rafrilianita@gmail.com

Abstract

This study aims to analyze the effect of carbon emission disclosure, eco-efficiency and green innovation on corporate value, as well as the moderating effect of environmental performance on the relationship between carbon emission disclosure and green innovation on corporate value. The sample in this study is the energy sector manufacturing companies listed on the Indonesian Stock Exchange for the 2022-2024 period. Quantitative analysis using the Moderated Regression Analysis (MRA) technique. It can be concluded that carbon emission disclosure, green innovation, environmental performance, and the interaction variables carbon emission disclosure × environmental performance, and green innovation × environmental performance simultaneously have a significant effect on corporate value. Eco-efficiency and eco-efficiency × environmental performance shows no significant effect on corporate value

Keywords: carbon emission disclosure, eco-efficiency, green innovation, corporate value, environmental performance

INTRODUCTION

The global industrial system has entered the era of Industry 5.0, where the focus is on synergy between humans and technology. However, this economic and technological progress has not been accompanied by progress in environmental aspects, resulting in many areas being polluted and damaged. The increase in pollutants in the environment and the overuse of natural resources have given rise to various issues such as global warming, eco-efficiency, and other industrial activities that directly impact the surrounding environment.

The World Top 10 (2023)

| Saudi Arabia | South Korea | Germany | Indonesia | Iran | Japan | Russia | India | United States | China |
| 1.6% | 1.6% | 1.5% | 1.8% | 2.1% | 2.7% | 4.8% | 7.8% | 13.2% | 32.5% |

Share of World

(*) Data Source: IEA (2024) *Greenhouse Gas Emissions from Energy.* All rights reserved.
(**) When 2023 data is missing, the figure refers to the latest available years.

According to the 2024 World Energy Review, Indonesia ranks 7th among the world's largest emitters. Indonesia's emissions consumption rate reaches 1.8%, higher than that of other developed countries. The large amount of carbon emissions is the result of fossil fuel combustion, typically generated by activities such as household industry, manufacturing, mining, transportation, and energy production for the consumption of goods and services (Rangga & Kristanto, 2023). The increasing growth of industrial activity is also proportional to the increasing pollution produced, which will contribute to carbon emissions that impact climate change.

Companies are required to prioritize not only management and shareholders, but also all related parties, such as employees, consumers, society, and the environment. According to the Triple Bottom Line theory, also known as The 3Ps (People, Planet, and Profit) proposed by Elkington (1998), the goal of business is not solely profit-making but also responsibility to the surrounding community and environment. Sustainable business practices are increasingly attractive to consumers and investors. Some consumers are willing to pay more for sustainable products. Governments, investors, employees, and consumers are also demanding new levels of corporate accountability, including action to address climate change. One effective corporate step in addressing the economic and social challenges in Indonesia is disclosing carbon emissions.

Environmentally responsible business practices can provide long-term benefits, such as increasing corporate value, gaining customer and stakeholder trust, and reducing environmental risks. Environmental performance can be measured by the PROPER rating in a company's sustainability report. In 2021, the government issued Presidential Regulation No. 98 of 2021 concerning the Implementation of Carbon Economic Value to meet the target of reducing greenhouse gas emissions according to the Nationally Determined Contribution (NDC). The Ministry of Environment and Forestry (KLHK) created the PROPER program for Corporate Performance Rating in Environmental Management. The instrument's working procedure involves disseminating information about a company's environmental performance to the public and stakeholders. The PROPER rating is divided into five color levels: black, red, blue, green, and gold.

This study modifies the previous study by Rahmasari and Irwansyah (2024), combining company efforts to mitigate global warming through disclosure of carbon emissions as the main factor of the greenhouse effect produced by the company and how the company's efforts in controlling environmental management with the intention of reducing the negative impact of the company on the environment and simultaneously creating more value for shareholders by implementing eco-efficiency. Eco-efficiency is an abbreviation of "ecological economic efficiency" which is a construct that shows increased productivity and is able to reduce costs with improved environmental performance (Meutia et al., 2019).

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Theoretical Framework: Stakeholders Theory, Signaling Theory and Goal Setting Theory

Stakeholder Theory was first introduced by the Stanford Research Institute in 1963, and defined as an organization that can provide support for the existence of an organization. According to Freeman (1989) in Tarigan (2014), he defines stakeholders as groups or individuals who can influence the achievement of an organization's goals.

Signaling theory was first proposed by Spence (1973) in his study titled "Job Market Signaling." In signaling theory, the primary objective of investment decisions can be influenced by various types of information available to a company. Disclosure of environmental information, such as credible sustainability reports, will lead to favorable investor perceptions, leading to investment decisions, as some investors will prefer companies that consistently disclose environmental information.

Goal-setting theory isn't limited to financial aspects alone; it also encompasses non-financial goal-setting. These non-financial goals include consumer engagement, product development, and innovation. For example, employees who contribute to long-term goals such as product development and innovation will be assessed and evaluated based on the success of their activities (Locke and Latham 2006).

The Impact of Carbon Emission Disclosure on Corporate Value

Stakeholders are more attracted to companies with strong financial and non-financial performance. This aligns with stakeholder theory, which describes organizational management and social performance. Investors and other stakeholders tend to respond positively to companies with high performance and environmental concerns. Therefore, companies' efforts to be more transparent about carbon emissions can play a significant role in enhancing the corporate 's value and reputation in the eyes of investors (Rahmasari & Irwansyah, 2024). These results also align with research by Kurniasari and Cahyono (2025), which found that carbon emission disclosure positively impacts corporate value.

The Impact of Eco-Efficiency on Corporate Value

Eco-efficiency plays a role in supporting companies in optimizing their productivity with minimal expenditure and reducing the negative environmental impacts of their activities (Apriandi & Lastanti, 2023). Thus, a company's production processes contribute to reducing waste and pollution.

Signaling theory is a theory used to provide signals to investors through the delivery of information regarding the company's condition by company management. Holding ISO 14001 certification indicates that a company is environmentally friendly and eco-efficient. This certification serves as a positive signal of the company's commitment to environmental concerns, thereby strengthening the company's credibility in the eyes of investors (Fanda & Dwijayanti, 2024). Research by Rahmasari and Irwansyah (2024) and Kurniasari and Cahyono (2025) aligns with this explanation, indicating that eco-efficiency influences corporate value.

The Impact of Green Innovation on Corporate Value

Sustainable development can be maximized by generating strong profits for the company, increasing dividends for investors and shareholders, and improving its social performance. This is in line with goal-setting theory, where companies consider not only their financial performance but also non-financial performance, such as development and innovation. Optimally implemented green innovation will increase operational efficiency in the use of raw materials and energy and create an environmentally friendly corporate environment (Rahmasari & Irwansyah, 2024).

This aligns with research by Sunarto et al. (2024) and Dianti and Puspitasari (2024), which provides evidence that green innovation impacts corporate value. By developing environmentally friendly product innovations, increasing a company's attractiveness ultimately has a positive impact on increasing corporate value.

The Effect of Carbon Emission Disclosure on Corporate Value with Environmental Performance as a Moderating Variable

An optimal carbon emissions disclosure strategy will build trust with investors and other stakeholders, thus laying the foundation for increasing corporate value. This can be achieved by disclosing carbon emissions and maintaining a commitment to minimizing their impact.

Research by Rahmasari and Irwansyah (2024) shows a positive correlation between carbon emissions disclosure and corporate value, but environmental performance fails to strengthen this relationship.

The Effect of Eco-Efficiency on Corporate Value with Environmental Performance as a Moderating Variable

The implementation of an eco-efficiency-based environmental strategy not only reflects corporate responsibility towards the environment but also has the potential to strengthen a company's competitive advantage and positively contribute to increasing the company's value in the eyes of stakeholders. Consistent with research by Marlina and Herawaty (2024), environmental performance moderates the relationship between eco-efficiency and corporate value.

The Effect of Green Innovation on Corporate Value with Environmental Performance as a Moderating Variable

In this advanced era, companies are required to adapt by continuously being creative and innovative. Equally important, companies also need to consider the impact of their operations. Implementing green innovation can be an effective way to address these issues, as it benefits the environment and can also attract investors and stakeholders.

Based on the above discussion, the following hypotheses are proposed:

H_1: The Impact of Carbon Emission Disclosure on CorporateValue

H_2: The Impact of Eco-Efficiency on Corporate Value

H_3: The Impact of Green Innovation on Corporate Value

H_4: The Effect of Carbon Emission Disclosure on Corporate Value

H_5: The Effect of Eco-Efficiency on Corporate Value with Environmental Performance as a Moderating Variable

H_6: The Effect of Green Innovation on Corporate Value with Environmental Performance as a Moderating Variable

METHOD

This study employed quantitative methods. The data used were secondary data, with hypothesis testing using multiple linear regression analysis using the Moderated Regression Analysis (MRA).

Tabel 1. Data Sources and Collection

Variabel	Sources	Period	Formula
Corporate Value	Financial Statement	2022-2024	Tobin's Q
Carbon Emission Disclousure	Sustainability Report	2022-2024	Carbon Emission Disclousure Checklist
Eco-Efficiency	Sustainability Report	2022-2024	Dummy Score
Green Innovation	Sustainability Report	2022-2024	GIN
Environmental Performance	PROPER	2022-2024	Gold score 5 (very good) Green score 4 (good) Blue score 3 (fair) Red score 2 (poor) Black score 1 (very poor)

Variables and measurement will use Multiple linear regression is used as an analytical tool to examine the relationships and influences between variables (Ghozali, 2013). The following is the form of multiple linear regression estimation:

Research Model 1:
$$Y = \beta 0 + \beta 1 X1 + \beta 2 X2 + \beta 3 X3 + \varepsilon$$
$$Y = \beta 0 + \beta 1 X1 + \beta 2 X2 + \beta 4 X1 * X4 + \beta 5 X2 * X4 + \varepsilon$$
X1= Carbon Emission Disclousure
X2= Eco-Efficiency
X3 = Green Innovation
Y= Corporate Value
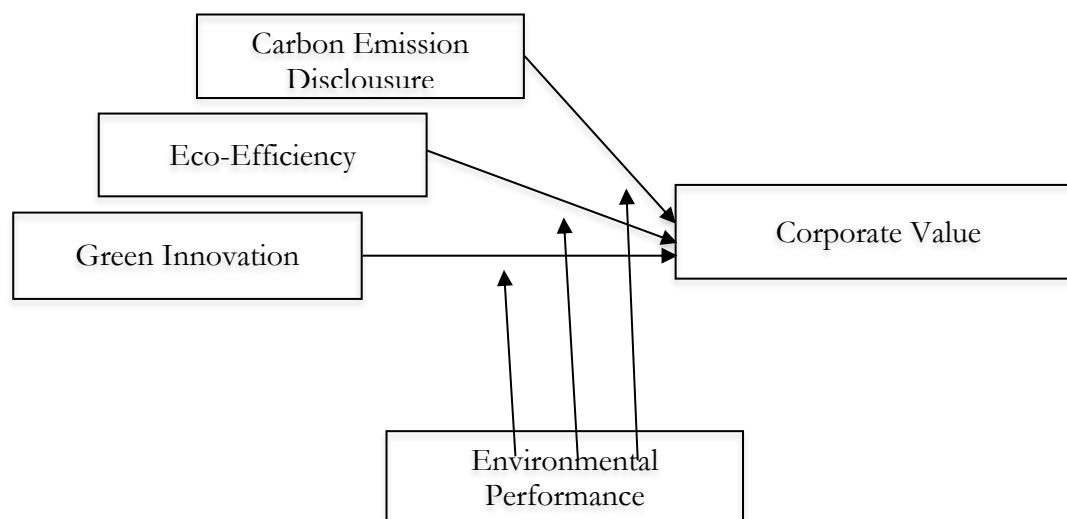Z= Environmental Performance
β= koefisien regresi

Figure 1. Research Model

RESULT AND DISCUSSION

This study employed quantitative methods. The data used were secondary data, with hypothesis testing using multiple linear regression analysis using the Moderated Regression Analysis (MRA) technique. The sampling technique used was purposive sampling, a deliberate selection method based on specific considerations. The unit of analysis was selected based on specific, predetermined criteria, ensuring that only subjects deemed most appropriate for the research objectives were included in the analysis. The following are the sample criteria for this study:

1. Energy sector manufacturing companies listed on the Indonesia Stock Exchange (IDX) for the 2022-2024 period.
2. Companies must present data including total assets, total liabilities, closing price, and number of shares outstanding.
3. Published a sustainability report and Financial statements for the 2022-2024 reporting period. The data obtained from these criteria are total observations 189.

Descriptive Analysis

Descriptive analysis is used to provide a systematic overview or summary of research data regarding the maximum, minimum, average (mean), and standard deviation values of the variables being studied. The goal is to determine the basic characteristics of the data before further analysis is conducted.

Table 2. Descriptive statistics

	N	Minimum	Maximur	Mean	Std. Deviation
Carbon Emission Disclosure	189	0.00	1.00	0.43	0.35
Eco-Efficiency	189	0.00	1.00	0.54	0.50
Green Innovation	189	0.00	1.00	0.42	0.26
Corporate Value	189	0.34	40.3	1.98	3.66
Environmental Performance	189	3.00	5.00	3.55	0.81

The Carbon Emission Disclosure variable (X1) has a maximum value of 1.00, which is found in several large energy companies such as PT Adaro Energy Indonesia Tbk (ADRO), PT Baramulti Suksessarana Tbk (BSSR), PT Bayan Resources Tbk (BYAN), PT Perusahaan Gas Negara Tbk (PGAS), and PT Indo Tambangraya Megah Tbk (ITMG) which consistently disclose all indicators related to carbon emissions. The minimum value of 0.00 is found in several small companies such as PT Capitol Nusantara Indonesia Tbk (CANI), PT Darma Henwa Tbk (DEWA), PT Bukit Perdana Tbk (PKPK), and several energy shipping companies that do not have sustainability reports. The average value of X1

is around 0.40–0.70, which indicates that in general energy companies have begun to disclose carbon emissions, although there are significant differences between large and small companies.

The Eco-Efficiency (X2) variable has a maximum value of 1.00, achieved by a number of companies that have highly efficient resource, energy, and waste management, such as ADRO, AKRA, BSSR, PGAS, ITMG, PTBA, and DSSA. The minimum value of 0.00 is found in companies such as CANI, DEWA, PKPK, TAMU, PTIS, and DWGL which do not show any environmental efficiency in their reporting. The average value of the X2 variable is in the range of 0.50, with a relatively large standard deviation, reflecting a significant difference in the ability of companies to manage energy and waste efficiency. This shows that large companies tend to be more efficient, while small companies show a low level of efficiency.

The Green Innovation variable (X3) has a maximum value of 1.00, which is owned by companies with solid implementation of environmentally friendly innovations, such as ADRO, BYAN, DSSA, INDY, ITMG, PGAS, and PTBA. The minimum value of 0.00 is found in companies that do not disclose green innovations, such as CANI, ARTI, PKPK, TAMU, FIRE, and DWGL. The average value of X3 is in the range of 0.30–0.60, which indicates that the level of green innovation in the energy sector is still developing, with most companies having innovations on a moderate scale, while small companies and those without SR tend not to carry out significant green innovations.

The Corporate Value variable, proxied using Tobin's Q, has a very high maximum value of 40.30, which was held by PT Akbar Indo Makmur Stimec Tbk (AIMS) in 2023 due to extreme stock price volatility. Meanwhile, minimum values of 0.55–0.60 were found in several companies with low market capitalizations such as WOWS, PTIS, or companies with weak fundamentals in a given year. The average Tobin's Q value is in the range of 1.50–2.00, with a high standard deviation indicating a wide spread in the data. This indicates that there are significant differences in market perceptions of energy companies.

The Environmental Performance (Z) variable has a maximum value of 5, which is the highest PROPER rating and is achieved by companies such as ADRO, PGAS, BSSR, BYAN, DSSA, ITMG, and PTBA that have excellent environmental management. A minimum value of 3 is given to companies with basic or lower environmental performance, such as shipping companies (HITS, PSSI), small mining companies (CANI, DEWA), and other small-scale energy companies. The average value is in the range of 3.5–4, indicating that most energy companies are in the Blue to Green PROPER category. Variations in the Z value indicate a gap between large companies that have a strong commitment to sustainability and small companies that still have limitations in environmental management.

Model Selection Test
In panel data analysis, the best model is selected using various tests, such as the Chow test, the Hausman test, and the Lagrange multiplier (LM) test.

A. Chow Test

Table 3. Chow Test

	Statistic	Prob.
Cross-section F	4.35	0.00
Cross-section Chi Square	222.75	0.00

Based on the results of the Chow test shown in the table above, it is known that the probability value is 0.0000, with the F and Chi-square statistical values also showing high significance. With a significance level of 5% ($\alpha = 0.05$), it can be concluded that the probability value is <0.05. This means that H_0 is rejected and H_1 is accepted, so the most appropriate model to use in this study is the Fixed Effect Model and the Hausman test must be carried out to analyze the data further.

B. Hausman Test

Table 4. Hausman Test

	Prob.
Cross-section roandom	0.16

Based on the results of the Hausman test shown in the table above, it is known that the probability value is 0.1601, greater than the 5% significance level ($\alpha = 0.05$). Thus, H_0 is accepted and H_1 is rejected, which means the most appropriate model to use in this study is the Random Effect Model (REM).

C. Lagrange Multiplier Test

Table 5. Lagrange Multiplier Test

	Prob.
Breusch-Pagan	0.00

From the test results shown in the table above, it is known that the probability value of Breusch-Pagan is 0.0000, which is smaller than the significance level of 0.05. Thus, H_0 is rejected and H_1 is accepted, which means that the most appropriate model used in this study is the Random Effect Model.

Classical Assumption Test

A. Normality Test

The normality test is a test used to determine whether the data obtained is normally distributed or not. The normality test in this study uses a normal probability plot graphic analysis approach. If the Jarque Berra Probability value is > 0.05, then the residual research data is normally distributed. The following are the results of the normality test in this study.

Table 6. Normality Test

Probability	0.59

Table 6 shows the Jarque Berra probability value of 0.54. This indicates that the residual data is normally distributed, as it meets the requirement that the probability value must be greater than 0.05. Therefore, it can be concluded that the data distribution in this study is normally distributed.

B. Multicollinearity Test

A multicollinearity test is performed to determine whether any independent variables are similar. A good regression model should have no correlation between the independent variables. In this study, the presence or absence of multicollinearity was determined by examining the VIF value. If the VIF value is <10, multicollinearity is not present.

Table 7. Multicollinearity Test

Variabel	VIF
Carbon Emission Disclousure	5.79
Eco-Efficiency	3.65
Green Innovation	6.18
Environmental Performance	4.14

Based on the results of the multicollinearity test shown in Table 7, it can be seen that all independent and moderator variables have Centered VIF values below 10. Because all Centered VIF values are below the threshold of 10, it can be concluded that there are no symptoms of multicollinearity in the regression model used in this study.

C. Heteroscedasticity Test

The heteroscedasticity test was conducted to determine whether there was inequality in residual variance between observations in the regression model. In this study, the heteroscedasticity test was conducted using the Breusch–Pagan–Godfrey test.

Table 8. Heteroscedasticity Test (Breusch-Pagan)

	Statistic	Prob.
F-statistics	0.71	0.59
Obs*R-Squared	2,86	0.58

Based on the test results shown in the following table, the F-statistic probability value is 0.59 and the Obs*R-squared probability value is 0.58, both of which are greater than 0.05. Thus, it can be concluded that the regression model is free from heteroscedasticity (homoscedasticity), making it suitable for use in further analysis.

D. Autocorrelation Test

The autocorrelation test aims to test whether there is a correlation between the nuisance error in period t and the nuisance error in period t-1 (previously) in the linear regression model. This study uses the Breusch-Godfrey test.

Table 9. Autocorrelation Test (Breusch-Godfrey)

	Statistic	Prob.
F-statistics	1.80	0.17
Obs*R-Squared	3.69	0.15

Based on the results of the Breusch–Godfrey Serial Correlation LM Test, the F-statistic probability value was 0.17 and the Chi-Square probability was 0.15. It can be concluded that the regression model used is free from autocorrelation problems.

B. t-Test

The t-test is used to determine the influence of each independent variable individually on the dependent variable, namely corporate value. The test is carried out with a significance level of 5% (α = 0.05). The number of observations in this study is 189, so the degrees of freedom (df) are calculated using the formula $n - k - 1 = 189 - 6 - 1 = 182$. Based on the two-way t-distribution, the t-table value at df = 182 and α = 0.05 is 1.973. Thus, a variable is declared to have a significant effect if the absolute value of the t-count is greater than the t-table ($|$t-count$|$ > 1.973) and the probability value is <0.05.

Table 10. t-Test

	t-Statistic
Carbon Emission Disclousure	14.15
Eco-Efficiency	-1.12
Green Innovation	-9.65
X_1Z	-12.38
X_2Z	1.05
X_3Z	10.77

Carbon Emission Disclosure has a significant positive effect on corporate value (H1), eco-Efficiency does not have a significant effect on corporate value (H2), Green Innovation has a significant influence on corporate value (H3). Environmental Performance significantly moderates the relationship between Carbon Emission Disclosure and corporate value. Because the coefficient is negative, this moderation weakens the relationship. Therefore, H4 is accepted (significant moderation), but it weakens the relationship. Environmental Performance does not moderate the effect of Eco-Efficiency on corporate value (H5). Environmental performance significantly moderates the relationship between green innovation and corporate value. The coefficient is positive, indicating that this moderation strengthens the relationship (H6).

C. F-Test

Table 11. F-Test

	Statistic
F-statistics	35.42
Prob	0.00

The F-statistic test is used to determine whether all independent variables and interaction variables in the model have a significant simultaneous effect on the dependent variable, namely corporate value. In this study, the number of observations is 189, so the degrees of freedom for the numerator (df1) is k = 6, and the degrees of freedom for the denominator (df2) is n – k – 1 = 189 – 6 – 1 = 182. With a 5% significance level (α = 0.05), the F-table value for df1 = 6 and df2 = 182 is approximately 2.17.

Based on the regression results, the calculated F-value is 35.42, which is significantly greater than the F-table (35.42 > 2.17) and the probability value is 0.00 < 0.05. Thus, it can be concluded that Carbon Emission Disclosure (X1), Eco-Efficiency (X2), Green Innovation (X3), Environmental Performance (Z), and the interaction variables X1×Z, X2×Z, and X3×Z simultaneously have a significant effect on corporate value. This indicates that the moderated regression model used in this study is significant overall.

E. Coefficient of Determination (R2)

Table 12. Coefficient of Determination

	Statistic
R-squared	0.54

The R-squared value obtained was 0.54, meaning that all independent variables and interaction variables in the model were able to explain 54% of the variation in corporate value. Meanwhile, the remaining 46% was influenced by variables outside the research model.

CONCLUSION

Based on the results of quantitative testing using the Moderated Regression Analysis (MRA) on 189 observations from energy sector manufacturing companies listed on the Indonesia Stock Exchange for the 2022–2024 period, several conclusions can be drawn.

First, the study finds that Carbon Emission Disclosure (X1) has a significant positive effect on corporate value. This indicates that companies that disclose carbon emissions more transparently tend to receive better assessments from investors and stakeholders, which in turn increases market value. Transparent disclosure serves as a positive signal regarding the company's environmental responsibility.

Second, Eco-Efficiency (X2) is found to have no significant effect on corporate value. This result suggests that efficiency improvements related to energy use, waste management, and

environmental cost reduction have not yet been fully recognized or valued by the market. Investors may perceive eco-efficiency efforts as internal operational activities that do not directly influence shareholder value.

Third, Green Innovation (X3) shows a significant effect on corporate value. Companies implementing environmentally friendly innovations—such as green products, clean technologies, and renewable energy initiatives—are perceived as more competitive and future-oriented. These innovations can enhance corporate image, operational effectiveness, and long-term sustainability, thereby increasing firm value.

Fourth, the moderating variable Environmental Performance (Z) shows varied roles. The interaction between Carbon Emission Disclosure × Environmental Performance (X1Z) has a significant but negative effect, meaning that environmental performance weakens the positive impact of carbon emission disclosure on corporate value. This suggests that when a company already has high environmental performance, additional disclosure of emissions may be viewed as less impactful by the market.

Fifth, the interaction between Eco-Efficiency × Environmental Performance (X2Z) shows no significant effect, demonstrating that environmental performance does not strengthen nor weaken the relationship between eco-efficiency and corporate value.

Sixth, the interaction between Green Innovation × Environmental Performance (X3Z) has a significant positive effect, indicating that environmental performance strengthens the influence of green innovation on corporate value. Companies that innovate while also maintaining strong environmental performance ratings receive higher market appreciation.

Finally, the simultaneous test (F-test) confirms that Carbon Emission Disclosure, Eco-Efficiency, Green Innovation, Environmental Performance, and all interaction (moderation) variables jointly have a significant effect on corporate value. The model's R-squared value of 0.54 indicates that 54% of the variation in corporate value can be explained by the variables included in this study, while the remaining 46% is influenced by other factors outside the model.

The study highlights the increasing importance of sustainability-oriented practices in shaping corporate value, especially through carbon transparency, green innovation, and environmental performance.

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