Implementation of carbon emission reduction and green innovation on investor reaction with environmental performance as a moderation variable

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Abstract: This research aims to explores the relationship between carbon emission reduction, green innovation, and investor reaction, with environmental performance acting as a moderating factor. Carbon accounting plays a vital role in tracking emissions and evaluating the success of environmental initiatives. Companies that demonstrate efforts to reduce their company's carbon emissions and implement green innovations to demonstrate their commitment to sustainability can reduce investment risks, thereby attracting investors to invest in the company. The population used in this study consists of manufacturing companies listed on the Indonesia Stock Exchange from 2020 to 2023, using a purposive sampling method. The research data utilized are secondary data in the form of annual reports obtained from the IDX website. The analytical method used is multiple linear regression analysis. The research results show that carbon emissions reduction and green innovation significantly negatively affects investor reactions. This is because there is still very little socialization from the company regarding operational activities in the environment towards the community as shareholders. Meanwhile, environmental performance could moderate the effect of carbon emission reduction and green innovation on investor reactions.

Keywords: Carbon emission reduction, Environmental performance, Green innovation, Investor reaction.

1. Introduction

Indonesia, as a large and diverse country, is increasingly challenged by the impact of climate change and environmental degradation. These issues have heightened the importance of sustainability across various sectors. According to Table 1, greenhouse gas emissions in Indonesia are on the rise, particularly from the manufacturing sectors.

Table 1.
Greenhouse gas emissions by industry (Gg CO2e), 2018-2022.

Industry	2018	2019	2020	2021	2022
Agriculture. forestry. and fishing	95.399	96.947	94.502	98.518	85.503
Mining and quarrying	36.961	38.082	25.514	29.352	29.280
Manufacturing	229.445	260.205	235.235	219.868	340.711
Electricity and gas supply	262.548	274.801	279.251	303.192	297.221
Water supply. sewerage. waste management and remediation activities	26.186	29.143	29.478	29.831	30.840
Transportation	83.948	74.850	65.066	66.292	81.082
Other industries	24.732	24.418	18.531	20.654	21.595
Total industry	759.219	798.447	747.579	767.707	887.233

Source: [1].

In response to this, Indonesian companies are under growing pressure to improve the transparency of their carbon emission reporting and to adopt green innovations. Companies that take these steps are

viewed more favorably by investors, as they demonstrate an ability to manage environmental risks and a commitment to long-term sustainability.

This study focuses on testing the impact of carbon emission reduction (measured through disclosure of carbon emission reduction actions) and green innovation on investor reactions in Indonesia), with environmental performance acting as a moderating factor. The insights gained from this research are expected to help policymakers and business leaders better incorporate sustainability into their corporate strategies.

2. Literature Review and Hypothesis Development

2.1. Literature Review

2.1.1. Legitimacy Theory

Legitimacy theory describes a social contract between a company and society [2]. Theory of legitimacy suggests that organizations must align with societal norms to maintain legitimacy, which is crucial for gaining stakeholder support and ensuring long-term survival [3]. Thus, it can be concluded that a company's sustainability depends on how well it uses its resources to fix and mitigate the environmental impacts of its operations [4].

In this context, companies can gain legitimacy from the public and investor by disclosing their carbon emissions, implementing environmental practices, and pursuing green innovations. These actions help companies build a positive image and earn legitimacy by showing they are responsible towards the environment. Thus, the legitimacy theory aligns with this research as it supports companies in fulfilling their social and environmental responsibilities and reflects the trust of the public in companies that consider environmental factors in their business practices.

2.1.2. Signal Theory

Information is a key element for investors because it provides records, details, and explanations about a company's past, present, and future, helping them assess the company's security and market position. The signaling theory emphasizes that the information companies publish impacts investment decisions [5]. The goal of the signal is a disclosure that include of promising future prospects, or even bad news [6].

The publication of reports on carbon emissions, green innovation, and environmental information reflects the company's transparency in revealing both financial and non-financial details. These disclosures, which provide positive information, are likely to receive favorable reactions from investors and attract potential investors, boosting the company's reputation. Additionally, companies release these reports to help reduce information asymmetry between themselves and investors.

2.2. Hypothesis Development

2.2.1. Emission Carbon Reduction and Investor Reaction

The reduction of carbon emissions is a significant contribution by companies to environmental impacts, particularly in relation to global warming issues [7]. Investors and stakeholders, who are increasingly paying attention to environmental issues, can interpret this disclosure as a positive indicator associated with good corporate governance and environmental responsibility.

The carbon emission disclosure has a direct impact on investor reaction [8]. Companies that offer comprehensive information about their carbon emissions can increase their value by drawing the attention of both current and prospective investors [9]. Companies that disclose carbon emissions will enable stakeholders to make informed decisions regarding the company's carbon performance and put pressure on the company to reduce its emissions [10]. It suggests that such disclosures offer positive insights to investor, influencing their investment decisions by reflecting the company's environmental commitment.

The study by [11] indicates that carbon emission reduction has a positive impact on investor reactions. This implies that the company will secure legitimacy and enhance its reputation, which will

positively influence investor reactions towards the sustainability of its business. Based on this and previous research, the researcher aims to investigate whether carbon emission reduction affects investor reaction, and the following hypothesis can be concluded:

H_1: *Carbon emission Reduction has a positive effect on investor reaction.*

2.2.2. Green Innovation to Investor Reaction

Green innovation refers to the development of products, services, and technologies that reduce environmental impact [12]. Green innovation has a magnificent effect on the company's competitive advantage and sustainability [13]. Based on study by [14], there is a relationship and encouragement between green innovation and investor reaction. Green innovation can enhance a company's image among investors [15]. It reveals that investor reaction is the goal and objective of the green innovation implementation.

Green innovation in a company is in line with legitimacy theory and signal theory. Implementing green innovation allows companies to enhance the transparency and accountability of their environmental impact [16]. Sustainability reporting, which contains information about green innovation, would supply investors with the necessary details to make informed investment decisions.

Based on this and previous research, the researcher aims to investigate whether green innovation affects investor reaction, and the following hypothesis can be concluded:

H_2: *Green innovation has a positive effect on investor reaction.*

2.2.3. Environmental Performance Moderates the Relationship between Carbon Emission Reduction and Investor Reaction

According to legitimacy theory, when a company voluntarily discloses its environmental performance in line with regulations, it enhances its public image, earning legitimacy for its business operations. The disclosure of information related to environmental performance can serve as a positive signal to stakeholders, as companies have voluntarily shared the information they require [4]. The research conducted by [6] resulted that the better a company's environmental performance and its disclosure, the more positive the investor response and the brighter the company's future prospects.

Various studies in developed countries reveal that investors, as key stakeholders, carefully consider a company's social and environmental performance when deciding on investments [6]. The implementation of environmental management by the company demonstrates its commitment to monitoring, managing, controlling, measuring, and reporting its environmental performance, including carbon emissions [11].

Based on this and previous research, the researcher aims to investigate whether environmental performance, can moderate the relationship between carbon emission reduction and investor reaction. The hypothesis can be stated as follows:

H_3: *Environmental performance moderates the relationship between carbon emission reduction and investor reaction.*

2.2.4. Environmental Performance Moderates the Relationship between Green Innovation and Investor Reaction

Environmental performance indicates how much a company is concerned about the environmental effects of its operations [10]. Since the community is also a part of the company's stakeholders, relying on legitimacy, companies should demonstrate strong social and environmental performances [4].

Investor response depends on the quality of information that the company provides to the public [17]. According to legitimacy theory, when a company accurately and voluntarily reports its environmental performance in line with regulations, the public will perceive the benefits [6]. Study conducted by [5] show that companies with strong environmental performance are likely to receive more positive responses from investors, leading to increased investment. This aligns with signaling theory, which underpins this research, indicating that disclosures that provide favorable signals, such as positive prospects, will elicit a positive response from external parties, including investors and users of the company's annual reports.

Based on this and previous research, the researcher aims to investigate whether environmental performance, can moderate the relationship between green innovation and investor reaction. The hypothesis can be stated as follows:

H_4: *Environmental performance moderates the relationship between green innovation and investor reaction.*
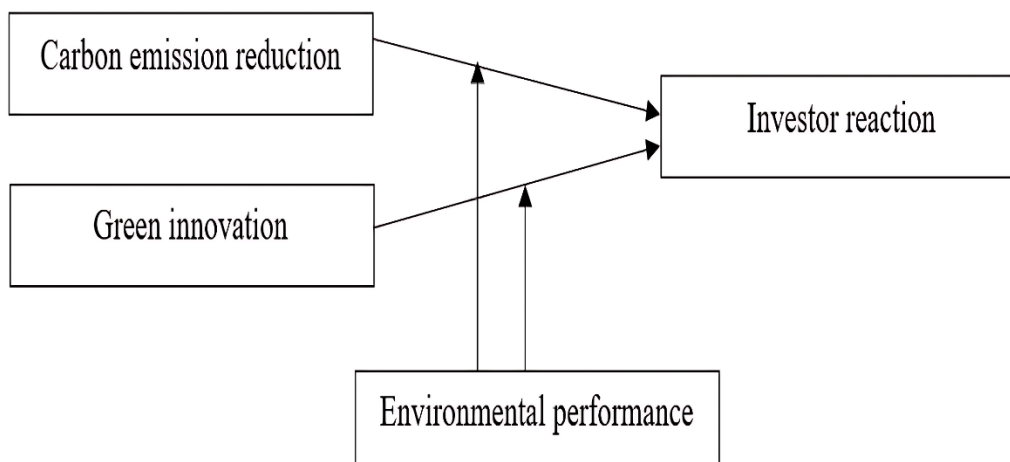
Figure 1.
Research model.

3. Research Method

The type of data used in this research is secondary quantitative data obtained from the annual reports of companies listed on the Indonesia Stock Exchange (IDX). The annual report period used in this study is from 2020 to 2023, based on the launch of the "GRI Standard" in 2020, which has been globally recognized as a standard reference for corporate sustainability and carbon emissions disclosure. The population consists of manufacturing companies, one of the industrial sectors that produces the largest carbon emissions. The sample selection was done using the purposive sampling method.

Table 2.
Research sample.

Information	Total
Manufacturing companies listed in IDX between 2020-2023.	152
Observation periods	4
Population total	608
Unavailable data	(298)
Sample total	310

The independent variable carbon emission reduction (measured by Carbon Emission Disclosure – CED), is measured using the content analysis method [10]. There are specific items that must be evaluated to determine the CED score from a company's annual report as shown in Table 3 below. For the calculation, there are 18 disclosure items, with each item being assigned a score of 0-1 based on its completeness. The total score is then divided by the total number of disclosure items, which is 18. The formula is as follows:

$$CED = \frac{Number\ of\ items\ revealed}{18}$$

Information:
CED = Carbon Emission Disclosure

Table 3.
Carbon emissions disclosure index.

Category	Item	Information	Score
Climate change: risks and opportunities	CC-1	Assessment/Description of the risks (regulatory, physical or general) relating to climate change and actions taken or to be taken to manage the risks.	1
	CC-2	Assessment/description of current (and future) financial implications, business implications and opportunities of climate change.	1
GHG emissions accounting	GHG-1	Description of the methodology used to calculate GHG emissions (e.g. GHG protocol or ISO).	1
	GHG-2	Existence external verification of quantity of GHG emissions (if so by whom and on what basis).	1
	GHG-3	Total GHG emissions (metric tonnes CO2-e emitted).	1
	GHG-4	Disclosure of Scopes 1 and 2, or Scope 3 direct GHG emissions.	1
	GHG-5	Disclosure of GHG emissions by source (e.g. coal, electricity, etc.).	1
	GHG-6	Disclosure of GHG emissions by facility or segment level.	1
	GHG-7	Comparison of GHG emissions with previous years.	1
Energy consumption accounting	EC-1	Total energy consumed (e.g. tera-joules or peta-joules).	1
	EC-2	Quantification of energy used from renewable sources.	1
	EC-3	Disclosure by type, facility or segment.	1
	RC-1	Detail of plans or strategies to reduce GHG emissions.	1
	RC-2	Specification of GHG emissions reduction target level and target year.	1
	RC-3	Emissions reductions and associated costs or saving achieved to date as a result of the reduction plan.	1
	RC-4	Cost of future emissions factored into capital expenditure planning.	1
Carbon emissions accountability	ACC-1	Indication of which board committee (or other executive body) has overall responsibility for actions related to climate change.	1
	ACC-2	Description of the mechanism by which the board (or other executive body) reviews the firm's progress regarding climate change	1
			18

Source: [19].

The next independent variable is green innovation, which refers to the company's ability to handle its impact on the environment through green and sustainable technology. The study conducted by [18] indicate that there is no uniformity of measurement in this area, and permanent statistics are not readily available. To address these gaps, there is a need to overcome methodological deficiencies by creating activity-specific indicators. Although some indicators for measuring green innovation exist, there is a need to develop more valid and reliable scales. In this research, the score assessment of the green innovation variable is divided into 1 (Very bad) – 5 (Very-very good), based on the level of green innovation.

Environmental performance is used as a moderating variable in this study which is measured by reviewing the PROPER (Corporate Performance Rating Assessment Program in Environmental Management) rating. This rating is coordinated and awarded by the Indonesian Ministry of Environment and Forestry which will review and supervise the company's performance in complying with environmental regulations. A higher rating reflects that the company has better integrity in implementing environmental regulations. The PROPER Rating System includes five colors:

Table 4.
Value of environmental performance.

Ranking	Information	Value
Gold	Very-Very Good	5
Green	Very Good	4
Blue	Well	3
Red	Bad	2
Black	Very Bad	1

Source: [10].

Investor reaction in this study will be used as the dependent variable, which will be measured using Cumulative Abnormal Return (CAR). The CAR calculation uses the Market Adjusted (Single Index Model) model where the model corrects the return value that is considered abnormal based on relevant market performance. The calculation of CAR for each issuer is the result of the accumulation of abnormal returns over an 11-day period, which includes 5 days before the annual report is published, 1 day on the event of the annual report publication, and 5 days after the annual report is published. CAR can be calculated by the formula:

$$CARit = \sum ARit$$

Information:

CARit = Cumulative abnormal return for stock i in period t

Arit = Abnormal return of stock i in period t.

Research data obtained from the IDX website in the form of company annual reports will be collected and processed before analysis in this study. After the data is collected, an analysis of the data obtained will be carried out and research conclusions drawn. The analytical technique used in this study is multiple linear regression to model the relationship between the independent and dependent variables, as well as the company's environmental performance as a moderating variable. To test whether the disclosure of carbon emissions and environmental innovation will affect investor reactions, and whether environmental performance will strengthen or weaken the relationship.

4. Result and Discussion

4.1. Descriptive Statistical Test

The results and discussion of this study begin by presenting a descriptive statistics table of research variables shown in Table 5.

Table 5.
Descriptive statistics.

Variable	Min	Max	Mean	Std. deviation
CER	0.00	0.89	0.4826	0.18481
GI	1.00	5.00	2.8103	0.97513
EP	3.00	5.00	3.0517	0.25803
IR	-0.00902	0.00864	-0.0000318	0.00288438

Note: CED = Carbon Emission Reduction
GI = Green Innovation
EP = Environmental Performance
IR = Investor Reaction

4.2. Normality Test

Based on what is shown in Table 5, the score value of the CER variable or disclosure of carbon emissions from the research sample, the maximum score obtained by the company during the study period was .89, with a standard deviation of .18481. During the study period, it was found that most companies were fully aware of disclosing their carbon emissions management.

Then for the GI or green innovation variable, the maximum score obtained by the company is 5.00, which indicates that the company has good green innovation performance, with the acquisition of the mean score of the GI variable 2.8103. Supported by the EP or environmental performance variable which has a mean value of 3.0517 with a maximum score of 5.00.

The average IR variable shows a negative result of -.0000318, indicating that, in general, the returns are negative. This suggests an increase in abnormal returns up until the day the company's information is disclosed, which is negatively responded to by investors. Therefore, in this study, the sample with negative investor reaction is more dominant than those with positive reaction, indicating that investor perceive the company's prospects as unfavorable. The standard deviation of IR is 0.00288438 (above average), meaning that IR has a high level of data variation.

Table 6.
Normality test.

Asymp. Sig.	0.093

The purpose of the normality test in Table 6 is to assess whether the independent and dependent variables in the regression model follow a normal distribution. The technique employed in this study is the Kolmogorov-Smirnov test. In this test, the Asymp. Sig value obtained is .093, which is greater than α (0.05), indicating that the data distribution is normal.

Table 7.
Multicollinearity test.

	CER	GI	EP
Tolerance	0.722	0.663	0.877
VIF	1.386	1.507	1.140

4.3. Multicollinearity Test

The testing method used to detect multicollinearity in regression is by examining the tolerance value and its counterpart, the Variance Inflation Factor (VIF). If the model's coefficient has a tolerance value > 0.10 and a VIF < 10, it can be concluded that multicollinearity is not present. Based on the calculation results in Table 7, it was found that all variables are free from multicollinearity, as indicated by the tolerance values > 0.10 and VIF values < 10. This shows that multicollinearity is not present, meaning there is no correlation between the independent variables.

Table 8.
Heteroscedascity test.

	CER	GI	EP
Sig.	0.267	0.508	0.356

4.4. Heteroscedasciticy Test

The heteroscedasticity test is conducted to determine if there is a violation of the classical assumption of heteroscedasticity, which refers to the unequal variance of residuals across all observations in the regression model. The statistical test used in this study is the Glejser Test. If the independent variable is statistically significant with a Sig. < 0.05, it indicates that heteroscedasticity is present. If the Sig. is greater than 0.05, it can be concluded that the regression model does not exhibit heteroscedasticity. Based on Table 8, it is found that the significance values of all variables are greater than the alpha value of 0.05, thus concluding that the regression model does not show signs of heteroscedasticity.

Table 9.
Autocorrelation test.

Durbin-Watson	2.164

4.5. Autocorrelation Test

The autocorrelation test is designed to determine whether there is a correlation between the disturbance errors at time t and the disturbance errors at time t-1, or the previous period, in a linear regression model. In this study, the Durbin-Watson test is used for autocorrelation testing. The decision-making process for determining the presence of autocorrelation using the Durbin-Watson table is as follows:

1. If 0 < d < dl, then there is no positive autocorrelation.
2. If dl ≤ d ≤ du, then there is no positive autocorrelation.
3. If 4 - dl < d < 4, then there is no negative correlation.
4. If 4 - du ≤ d ≤ 4 - dl, then there is no negative correlation.

5. If du < d < 4 – du, then there is no positive or negative autocorrelation.

In Table 9, the calculation resulted the value of d is 2.164. Therefore, it can be concluded that the model falls into the fifth category, i.e., du < d < 4 – du, which indicates that there is no autocorrelation in the regression model.

4.6. Hypothesis Testing

In order to examine the effects of the independent, moderator, and dependent variables, Moderated Regression Analysis (MRA) was applied. The model specification utilized in this research is outlined as follows:

$$IR = \alpha + \beta_1 CER + \beta_2 GI \tag{1}$$
$$IR = \alpha + \beta_1 CER + \beta_2 GI + \beta_3 EP + \beta_4 CER*EP + \beta_5 GI*EP \tag{2}$$

Note:
CED = Carbon Emission Reduction
GI = Green Innovation
EP = Environmental Performance
IR = Investor Reaction

Table 10.
Determination coefficient test.

R Square	0.005

In the Table 10 above, the R Square value is 0.005. This means that the independent variables, namely carbon emission reduction and green innovation, can explain 0.5% of the variance in the dependent variable, which is investor reaction. The remaining 99.5% is explained by other variables that are not part of the scope of this study.

Table 11.
F test.

F-Statistic	Sig.
0.590	0.555

Based on the calculation on Table 11, the obtained F-Statistic value is 0.590, which is smaller than the F-table value. The Sig. value is 0.555, which is greater than 0.05, leading to the rejection of the Ha hypothesis.

Table 12.
T test.

	Coefficient	t	Sig.	Conclusion
CER	0.001	0.760	0.448	H1 not support
GI	0.000	0.259	0.796	H2 not support
EP*CER	0.006	2.373	0.018	H3 support
EP*GI	0.001	2.515	0.013	H4 support

Table 12 result states that the reduction of carbon emissions is not enough to significantly affect investors' reactions to the company. This study is in line with the study conducted by [5], which states that carbon emission disclosure does not have a positive impact on investor reaction. Even if a company's annual report includes at least one element of carbon emission disclosure, it does not necessarily lead to a positive investor reaction towards investing in the company. The most likely reason is that information about greenhouse gases, carbon emissions, and their disclosure has not been effectively communicated to investors. Additionally, carbon emissions reduction practices is often seen as an extra cost without clear benefits [17].

Green innovation does not have a significant impact on investor reaction. Although widely recognized as a proactive corporate strategy, this variable is not yet strong enough to significantly influence investor reaction. Despite being aligned with the legitimacy and signal theory — which suggests that such actions should send positive signals to investors regarding the company's commitment to sustainability — the findings suggest that other factors, such as the lack of clear standards for measuring green innovation, may have a greater influence on investor reactions. In the context of Indonesia, awareness of environmental issues among investors might still be relatively low, meaning green innovation initiatives have yet to receive the recognition they deserve.

This study provides reinforcement to the environmental management practices carried out by companies. Evidently, this study confirms that environmental performance can moderate the relationship between carbon emission reduction and green innovation carried out by companies on investor reactions in the capital market. The results showed that states that environmental performance can moderate the relationship between carbon emission reduction and green innovation with investor reaction. This indicates that good corporate environmental performance can strengthen the effect of carbon emission reduction and green innovation on investor reaction. This is in line with stakeholder theory and signal theory, which form the theoretical basis of this study. These theories suggest that companies that disclose their environmental performance (as a form of engagement with society) and provide a good signal, such as showing positive prospects, will receive a favorable response from external parties, in this case, investors. The implementation of environmental performance by a company shows its commitment to monitoring, managing, controlling, measuring, and reporting its environmental performance, specifically in terms of carbon emission reduction and green innovation [11]. It is said that companies that carry out their environmental performance well will benefit positively.

5. Conclusion

5.1. Conclusion

This study successfully confirms that environmental performance is a powerful corporate activity in building positive sentiment for capital market players, especially investors. The research findings indicate that carbon emission reduction and green innovation do not have a positive effect on investor reactions. Environmental performance, as a moderating variable, can strengthen the relationship between carbon emission reduction and green innovation with investor reactions.

5.2. Limitation

There is still an element of subjectivity in determining the green innovation index, as well as in evaluating it. This is due to the absence of a standardized benchmark that can be used as a reference, resulting in the index determination for the green innovation variable differing across various studies

5.3. Recommendation

The research model can be modified by adding other variables to improve the research findings.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Copyright:

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