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Determinants of Carbon Disclosure: The Role of Sustainability Assurance, Board Independence, Institutional Ownership and Gross Domestic Product in Mining Companies Across Five ASEAN Countries

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Abstract: This study aims to analyze the effect of Sustainability Assurance, Board Independence, Institutional Ownership, and Gross Domestic Product on Carbon Disclosure in Mining Companies Across Five ASEAN Countries (Indonesia, Malaysia, Filipina, Singapura, Thailand). This research applies a quantitative approach using secondary data obtained from annual reports and sustainability reports during the period from 2022 to 2024. Sustainability Assurance and Carbon Disclosure are measured through content analysis based on ISAE 3000 and TCFD, while the hypotheses are tested using panel data regression with the Fixed Effect Model. The results show that Sustainability Assurance and Institutional Ownership have a positive and significant effect on Carbon Disclosure, while Board Independence and Gross Domestic Product have a positive but insignificant effect. This study recommends that companies improve the quality of carbon reporting and strengthen the reliability of sustainability information through more comprehensive assurance practices.

Keywords: Sustainability Assurance, Board Independence, Institutional Ownership, Gross Domestic Product, Carbon Disclosure

INTRODUCTION

Climate change is now seen as an increasingly pressing global issue because its impacts are not only felt in environmental aspects but also influence the formation of public policy, the direction of business strategies, and corporate reporting patterns in various countries. Therefore, carbon disclosure plays a crucial role because it represents a company's commitment to presenting emissions information in a transparent, clear, measurable, and useful manner to stakeholders (Guo et al., 2022).

The urgency of carbon disclosure is increasing in line with Asia's strong position in global mining activities. World Mining Data 2026 shows that global mining production in 2024 will reach approximately 19.44 billion metric tons, with Asia contributing approximately 12.19 billion metric tons, or 62.7% of total production (World Mining Data, 2026). Among various business sectors, mining is one of the most worthy of study because its operational activities are directly linked to the use of natural resources, the potential for environmental degradation,

high energy consumption, and increased carbon emissions (Amegboleza et al., 2025). Therefore, the mining sector is a relevant research context for analyzing carbon disclosure practices due to its industry characteristics and high levels of environmental exposure.

This research focuses on five ASEAN countries: Malaysia, Thailand, the Philippines, Indonesia, and Singapore. Furthermore, environmental regulations in the ASEAN region are not yet fully implemented uniformly, so differences in carbon disclosure levels are potentially influenced by variations in policies, regulatory pressures, and external conditions prevailing in each country (Suhardianto et al., 2026). A study by Gunawan et al. (2023) shows that corporate decarbonization in Malaysia still focuses on environmental regulatory compliance and cost savings, strengthening the relevance of this study, as Malaysia is one of the sample countries and emphasizing the importance of carbon disclosure to make corporate decarbonization commitments more transparent, measurable, and accountable.

One of several factors thought to influence carbon disclosure is Sustainability Assurance, a process of independent assurance of a company's sustainability information aimed at strengthening the reliability, credibility, and level of trust of report users in the non-financial information presented (Hazaea et al., 2022). The study by Oktantiani & Gunawan (2023) explains that sustainability report assurance plays an important role in increasing report users' trust and the credibility of corporate sustainability information, making it relevant to this study because carbon disclosure in mining companies requires information that is not only narrative but also trustworthy, verifiable, and accountable to investors, regulators, and the public.

Another factor thought to influence carbon disclosure is Board Independence (Wahyuningrum et al., 2025). In addition to oversight through board structure, institutional ownership is also seen as a factor that can influence carbon disclosure (Kordsachia et al., 2022). In addition to internal company factors, this study also includes Gross Domestic Product (GDP) as a country-level factor suspected of influencing carbon disclosure (Helfaya et al., 2023). Company size in this study refers to the size of a company's economy of scale, measured using the natural logarithm of total assets, as this measure is considered more comparable when used to compare companies with varying asset values (Al-Kubaisi et al., 2025).

Theoretically, this study is based on the Legitimacy Theory proposed by John Dowling and Jeffrey Pfeffer (1975). This theory explains that companies must balance their disclosure activities and practices with societal norms, values, and expectations so that their existence continues to gain social acceptance, making it relevant to explain the relationship between Sustainability Assurance, Gross Domestic Product, and Carbon Disclosure (Suhardianto et al., 2026). On the other hand, this study also applies the Stakeholder Theory introduced by Robert Edward Freeman (1984), a theory that emphasizes that corporate responsibility is not only directed to shareholders, but also to various parties who influence or are influenced by the company's activities, making it appropriate to explain the role of Board Independence and Institutional Ownership in encouraging environmental information disclosure (Dahiru et al., 2026).

Previous studies have also examined carbon disclosure in the ASEAN region. For example, Suhardianto et al. (2026) investigated the influence of sustainability assurance on carbon disclosure across five ASEAN countries. However, the study did not specifically focus on mining companies and measured sustainability assurance using only a dummy variable indicating the presence or absence of assurance.

This study extends previous research by measuring Sustainability Assurance using ISAE 3000-based content analysis, allowing assurance quality to be evaluated based on the completeness of assurance report elements rather than merely its existence (Baier et al., 2022). In addition, unlike Suhardianto et al. (2026), which relied on LSEG Refinitiv data, this study measures Carbon Disclosure directly through TCFD-based content analysis of annual reports and sustainability reports. This approach enables a more comprehensive evaluation of governance, strategy, risk management, and climate-related metrics and targets, thereby providing a more detailed assessment of disclosure quality (Principale et al., 2023).

Another contribution of this study lies in the development of a more comprehensive research model. Previous studies have separately examined board effectiveness (Wahyuningrum et al., 2025), institutional ownership (Kordsachia et al., 2022), or macroeconomic factors such as Gross Domestic Product (Helfaya et al., 2023). However, limited studies have simultaneously investigated Sustainability Assurance, Board Independence, Institutional Ownership, and Gross Domestic Product within the mining industry across five ASEAN countries. Therefore, this study integrates corporate governance, ownership structure, assurance practices, and macroeconomic conditions into a single empirical model to provide a more comprehensive explanation of carbon disclosure.

Overall, the novelty of this research lies in three aspects. First, Sustainability Assurance is measured using ISAE 3000-based content analysis rather than a dummy variable. Second, Carbon Disclosure is assessed directly using the TCFD framework instead of relying on secondary ESG databases. Third, this study focuses on mining companies across five ASEAN countries while simultaneously incorporating Board Independence, Institutional Ownership, and Gross Domestic Product into a unified research model. Therefore, this study is expected to enrich the carbon disclosure literature by providing more comprehensive empirical evidence regarding the determinants of carbon disclosure in environmentally sensitive industries.

METHOD

This study uses a quantitative approach with a causality research design to examine the influence of Sustainability Assurance, Board Independence, Institutional Ownership, and Gross Domestic Product (GDP) on Carbon Disclosure in mining companies in five ASEAN countries: Indonesia, Malaysia, Thailand, the Philippines, and Singapore, during the 2022-2024 period. The study population included all companies in the mining sector or subsector listed on the stock exchanges of each country, totaling 113 companies. The study employed a saturated sampling method, ensuring that all members of the population were sampled as long as data was available during the observation period. The data used were secondary data obtained from annual reports and corporate sustainability reports on the companies' official websites. Gross Domestic Product (GDP) and USD exchange rate data were obtained from World Bank Data. This study used unbalanced panel data because the completeness of data for each company varied across years.

Data analysis was conducted in two main stages. The first stage used content analysis to convert narrative information in company reports into carbon disclosure scores based on the research indicators (Krippendorff, 2019). Next, the relationships between variables were analyzed using panel data regression with the aid of EViews 9 software, considering that the research data combines cross-sectional dimensions (113 mining companies) and time series (2022-2024). The analysis stages included panel data preparation, descriptive statistical analysis, selection of the most appropriate panel regression model, model feasibility testing, and partial hypothesis testing to obtain empirical evidence regarding the influence of Sustainability Assurance, Board Independence, Institutional Ownership, and Gross Domestic Product on Carbon Disclosure in mining companies in five ASEAN countries.

Sustainability Assurance

In this study, sustainability assurance is measured through a content analysis method with reference to assurance report indicators based on ISAE 3000 Revised issued by the IAASB in 2013, as presented in Table 1:

Table 1. Sustainability Assurance Indicators

No.	Indicator	Disclosure Indicators
1.	Title	The report title clearly indicates “independent assurance report” and is distinguishable from other reports.
2.	Addressee	Information on the intended recipient of the assurance report, including the engaging party and other specific users.

3.	Subject Matter and Underlying Matter Information	Information on the level of assurance, the subject matter examined and its basis, including the measurement period, the responsible party, the characteristics of the information, and any changes affecting comparability between periods.
4.	Applicable Criteria	Information on the criteria used to measure or evaluate the subject matter, including the source, legal basis, method, significant interpretations, and changes in the method.
5.	Inherent Limitations	Information on any significant inherent limitations in the measurement or evaluation of the subject matter, so users understand that the assurance results have certain limitations.
6.	Specific Objectives	Information that the criteria are designed for a specific purpose, so the subject matter may not be suitable for other purposes.
7.	Respective Responsibilities of Each Party	Information on the responsible party, the measurer, or evaluator, if different, and the respective responsibilities of each party and the assuror in reaching an independent conclusion.
8.	Performance of the Engagement in Accordance with ISAE 3000	Information that the engagement was conducted in accordance with ISAE 3000 is clearly and not misleadingly stated.
9.	Applicable Quality Control Requirements	Information on the assuror firm's implementation of quality control requirements, including documented policies and procedures.
10.	Compliance with Independence and Other Ethical Requirements	Information on the assuror's compliance with independence and other ethical requirements, such as the IESBA Code of Ethics or equivalent requirements.
11.	Summary of Work Performed	Information on the summary of the work as the basis for the assuror's conclusion, including an explanation that Limited Assurance procedures differ from and are less stringent than those for Reasonable Assurance.
12.	Assuror's Conclusion	Information on the assurer's conclusion, either in the form of a positive statement for Reasonable Assurance or a statement of no material findings for Limited Assurance, along with an explanation of any modifications to the conclusion.
13.	Assuror's Signature	Information on the assurer's signature as an endorsement of the report, including the firm's name, the individual assuror's name, or both, depending on the jurisdiction.
14.	Date	Information on the date of the report, indicating that the assuror has obtained sufficient evidence to base the conclusion.
15.	Location	Information on the location or jurisdiction where the assurer practices, as the place where the assurance report is issued.

Source: ISAE 3000 Revised for IAASB (2013)

The assessment process is carried out by assigning a score based on the completeness of the information disclosed in the sustainability report. The scoring criteria used in this study are outlined in Table 2:

Table 2. Sustainability Assurance Assessment Criteria

Score	Description
0	The item is not disclosed in the report
1	The item is disclosed briefly, i.e., less than three sentences
2	The item is disclosed more fully, i.e., at least three sentences, one paragraph, or more than one page

Source: Wahyuningrum et al. (2025)

The average sustainability assurance score in this study was calculated using the formula below:

$$SA = \frac{Total\ Score\ Obtained\ by\ the\ Company}{Maximum\ Score}$$

Board Independence

Regarding carbon disclosure, the greater the proportion of independent board members, the greater the company's opportunity to have more objective oversight of sustainability

reporting policies and environmental information disclosure (Kim et al., 2023). The formula used to measure board independence is:

$$INBRD = \frac{Number\ of\ Independent\ Board\ Member}{Total\ Board\ Member}\ x\ 100\%$$

Institutional Ownership

In the context of carbon disclosure, institutional ownership can encourage companies to provide more transparent sustainability information, as institutional investors increasingly consider environmental risks in their investment decision-making processes (Mukti et al., 2025). The formula used to measure institutional ownership is:

$$INSOWN = \frac{Number\ of\ Share\ Owned\ by\ Institutions}{Number\ of\ Shares\ Outstanding}\ x\ 100\%$$

Gross Domestic Product

The Gross Domestic Product (GDP) data in this study was obtained from World Bank Open Data for five ASEAN countries for the period 2022 to 2024.

Table 3. Gross Domestic Product Data per Country and per Year

Country Name	2022 (US$)	2023 (US$)	2024 (US$)
Indonesia	1,319,101,183,380.15	1,371,169,301,563.62	1,396,300,098,190.97
Malaysia	407,830,525,989.55	399,949,418,752.66	422,227,005,428.69
Filipina	404,353,369,604.63	437,055,627,244.42	461,617,509,782.36
Singapura	509,017,841,146.56	505,439,514,078.02	547,386,645,891.85
Indonesia	1,319,101,183,380.15	1,371,169,301,563.62	1,396,300,098,190.97

Source: World Bank Open Data, 2026

After the Gross Domestic Product data was obtained, the original nominal value was converted into natural logarithm (Ln) form. The formula used to measure Gross Domestic Product is:

$$GDP = Ln\ (Gross\ Domestic\ Bruto)$$

Carbon Disclosure

In this study, carbon disclosure was measured through a content analysis method using TCFD indicators, which refer to the 2019 SASB & CDSB guidelines. The indicators used in this study are outlined in Table 4:

Table 4. Carbon Disclosure Indicators

No.	Core Elements	Disclosure Indicators
1.	Governance	Describe the board's oversight of climate-related risks and opportunities.
		Describe management's role in assessing and managing climate-related risks and opportunities.
2.	Strategy	Describe the climate-related risks and opportunities the organization has identified over the short, medium, and long term.
		Describe the impact of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning.
		Describe the resilience of the organization's strategy, taking into consideration different climate-related scenarios, including a 2°C or lower scenario.
3.	Risk Management	Describe the organization's processes for identifying and assessing climate related risks.
		Describe the organization's processes for managing climate-related risks.
		Describe how processes for identifying, assessing, and managing climate related risks are integrated into the organization's overall risk management.

4.	Metrics and Targets	Disclose the metrics used by the organization to assess climate-related risks and opportunities in line with its strategy and risk management process.
		Disclose Scope 1, Scope 2, and, if appropriate, Scope 3 greenhouse gas (GHG) emissions, and the related risks.
		Describe the targets used by the organization to manage climate-related risks and opportunities and performance against targets.

Source: SASB Foundation and Climate Disclosure Standards Board (2019)

The assessment process is carried out by assigning a score based on the completeness of the information provided in the sustainability report. The scoring criteria used in this study are outlined in Table 5:

Table 5. Carbon Disclosure Assessment Criteria

Score	Description
0	The item is not disclosed in the report.
1	The item is disclosed briefly, i.e., less than three sentences.
2	The item is disclosed more fully, i.e., at least three sentences, one paragraph, or more than one page.

Source: Wahyuningrum et al. (2025)

The average carbon disclosure score in this study was calculated using the formula below:

$$CD = \frac{Total\ Score\ Obtained\ by\ the\ Company}{Maximum\ Score}$$

Company Size

Larger companies typically have more adequate resources, better reporting capabilities, higher public attention, and stronger pressure from stakeholders and regulators. Total company asset data from five ASEAN countries were first converted into US$ because each country uses a different currency. USD exchange rate data was obtained from World Bank Open Data.

Table 6. USD Exchange Rate Data per Country and per Year

Country Name	2022 (US$)	2023 (US$)	2024 (US$)
Indonesia	14,849.85	15,236.88	15,855.45
Malaysia	4.40	4.56	4.58
Filipina	54.48	55.63	57.29
Singapura	1.38	1.34	1.34
Thailand	35.06	34.80	35.29

Source: World Bank Open Data, 2026

After total assets are converted to USD, company size is measured using the natural logarithm (Ln). The formula used to measure company size is as follows:

$$SIZE = Ln\ (Total\ Asset)$$

Conceptual Framework

The conceptual framework in Figure 1 is based on Legitimacy Theory and Stakeholder Theory and is supported by previous research explaining the relationship between Sustainability Assurance, Board Independence, Institutional Ownership, and Gross Domestic Product with Carbon Disclosure. In this study, Carbon Disclosure is positioned as the dependent variable, while Sustainability Assurance, Board Independence, Institutional Ownership, and Gross Domestic Product are the independent variables. Furthermore, Company Size is used as a control variable to control for the influence of company characteristics on the level of carbon disclosure.

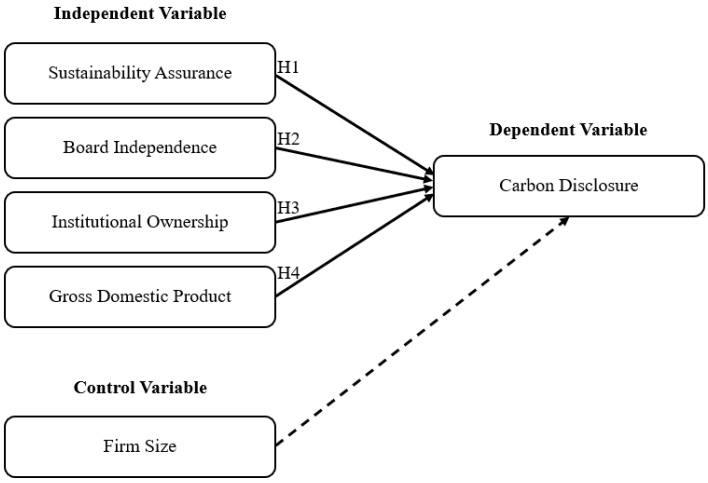


Figure 1. Conceptual Framework

Based on this conceptual framework, this study formulates several hypotheses to empirically test the direction and significance of the relationships between the variables, as follows: a) H1: Sustainability Assurance has a positive effect on carbon disclosure; b) H2: Board independence has a positive effect on carbon disclosure; c) H3: Institutional ownership has a positive effect on carbon disclosure; d) H4: Gross Domestic Product has a positive effect on carbon disclosure.

RESULTS AND DISCUSSION

Results

Table 7. Number of Samples Tested

No.	Description	Total
1.	Indonesia	41
2.	Malaysia	33
3.	Filipina	18
4.	Singapura	16
5.	Thailand	20
Total Company Population		**128**
Research Period		3
Initial Sample Size		**384**
Eliminated Zero-Value Samples		(62)
Final Sample Size Used		**322**

Based on the data review process, there were 62 observations with a value of 0.000000 for one or more research variables, so these observations were eliminated from the final sample. Elimination was carried out because a value of 0.000000 indicated that the data on a particular variable did not meet the measurement criteria required in the study, thus affecting the quality of the descriptive statistics results and panel data regression testing. After the 62 observations with zero values were removed, the number of data suitable for use in the analysis became 322 observations, so the final sample was considered more representative in explaining the influence of Sustainability Assurance, Board Independence, Institutional Ownership, and Gross Domestic Product on Carbon Disclosure.

Descriptive Statistics

Table 8. Descriptive Statistics Results

Variables	N	Mean	Median	Maximum	Minimum	Std. Dev.
Carbon Disclosure	322	0,5116	0,5000	1,0000	0,0455	0,2727

Sustainability Assurance	322	0,4473	0,4333	1,0000	0,1333	0,1605
Board Independence	322	0,4703	0,4545	1,0000	0,2000	0,1376
Institutional Ownership	322	0,5991	0,6298	1,0000	0,0003	0,2650
Gross Domestic Product	322	27,2391	26,9692	27,9649	26,7146	0,5351
Company Size	322	19,5527	19,2725	24,0697	16,3591	1,6258

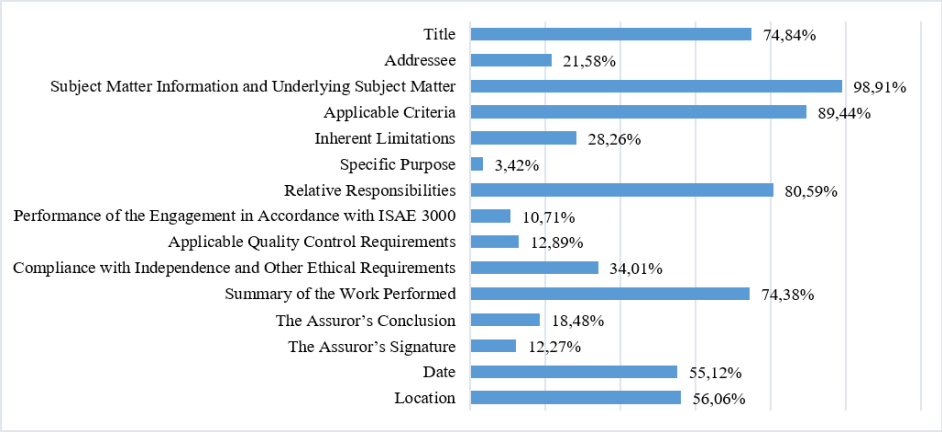
Source: Data processed by researchers with EViews 9, 2026

Table 8 presents the descriptive statistics from 322 research observations. The Carbon Disclosure variable has an average value of 0.5116, indicating that mining companies in the five ASEAN countries have disclosed approximately 51.16% of carbon disclosure indicators. Sustainability Assurance has an average value of 0.4473, indicating that the quality of assurance implementation is still at a moderate level. Meanwhile, Board Independence and Institutional Ownership have average values of 0.4703 and 0.5991, respectively, indicating that the proportion of independent board members is close to half of the board, while share ownership by institutional investors reaches approximately 60% of total ownership.

The Gross Domestic Product variable has an average value of 27.2391 with relatively low data dispersion (standard deviation of 0.5351), indicating that differences in economic conditions between the sample countries are not significant. In contrast, Firm Size had a mean of 19.5527 and the largest standard deviation of 1.6258, indicating significant variation across firm sizes. Overall, the descriptive statistics show that all research variables have sufficient data variation, making them suitable for further analysis using panel data regression.

Analysis of Content Analysis Results

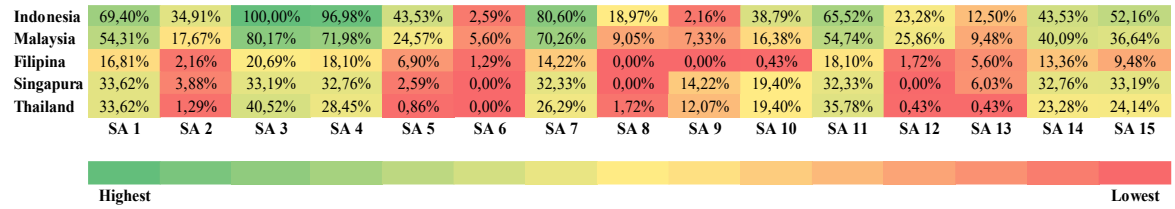
Results of Content Analysis Sustainability Assurance



Source: Data processed by researchers using Excel, 2026

Figure 2. Percentage of Sustainability Assurance Indicators

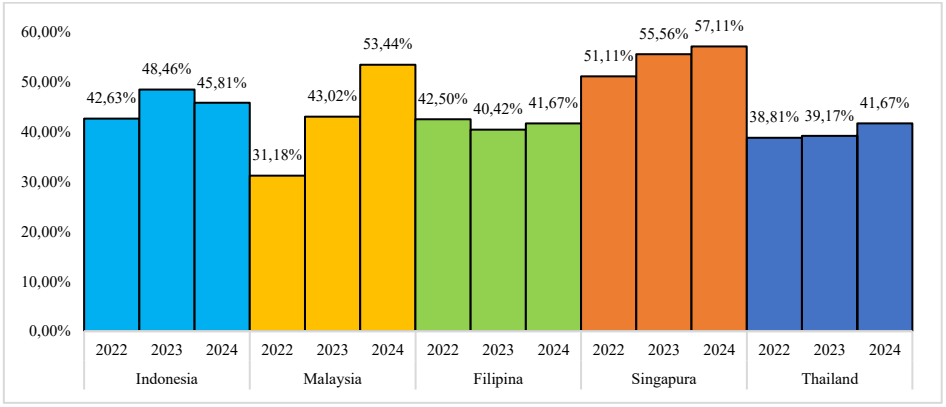
Based on Figure 2, mining companies in the five ASEAN countries tend to have high levels of disclosure on sustainability assurance indicators related to the report content, such as Information on the Main Matter and Underlying Matter (98.91%), Applicable Criteria (89.44%), and Responsibilities of Each Party (80.59%). Conversely, several indicators related to the formal aspects of the assurance process still show low levels of disclosure, particularly Specific Purpose (3.42%), Implementation of the Engagement in Accordance with ISAE 3000 (10.71%), Assuror Signature (12.27%), and Applicable Quality Control Requirements (12.89%). This finding indicates that companies have been quite good at disclosing the substance of their sustainability reports, but have not yet fully presented information regarding the assurance process and external verification comprehensively. Therefore, the quality of sustainability assurance disclosures still varies among mining companies in the ASEAN region.



Source: Data processed by researchers using Excel, 2026

Figure 3. Heatmap of Sustainability Assurance Indicators

Figure 3 presents a comparison of the disclosure levels of Sustainability Assurance indicators across five ASEAN countries. In general, Indonesia, Malaysia, the Philippines, and Thailand demonstrated the highest levels of disclosure for the Subject Matter and Underlying Subject Matter indicators, while Singapore had the highest level of disclosure for the Title indicator. Conversely, indicators related to formal assurance aspects, such as Specific Purpose, Conduct of Engagement in Accordance with ISAE 3000, and Applicable Quality Control Requirements, still have low disclosure levels in most countries. These findings indicate that although sustainability assurance practices have developed among mining companies in the ASEAN region, the quality of disclosure remains uneven. Companies tend to disclose more about the substance of their sustainability reports than about the assurance process, suggesting that improvements in assurance quality are still needed to strengthen the credibility of carbon disclosures and sustainability reports.

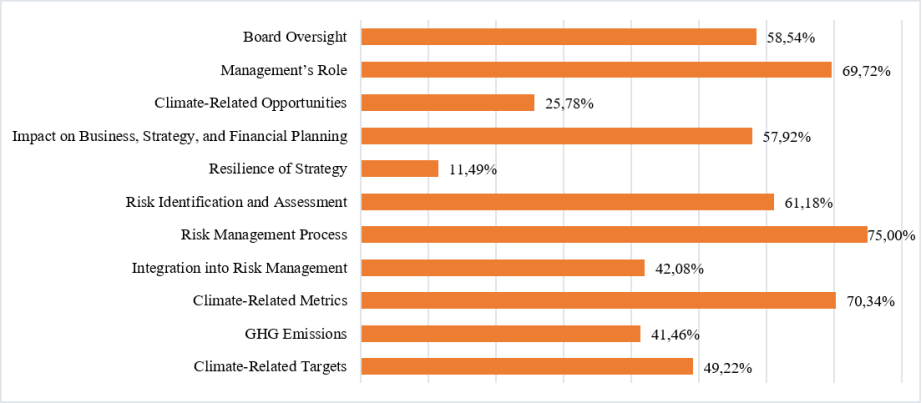


Source: Data processed by researchers using Excel, 2026

Figure 4. Average Sustainability Assurance Indicators

Figure 4 shows the average development of Sustainability Assurance indicators in mining companies across five ASEAN countries during the 2022-2024 period. Overall, Malaysia recorded the highest increase (22.26 percentage points), followed by Singapore (6.00 points), Indonesia (3.18 points), and Thailand (2.86 points), while the Philippines experienced a slight decline (0.83 points). These findings indicate that the implementation of Sustainability Assurance in the ASEAN region has progressed, but the level of progress varies across countries. These differences reflect variations in regulations, governance quality, and stakeholder pressure on sustainability reporting. Therefore, these results suggest that strengthening sustainability assurance standards is still needed to improve the quality, consistency, and comparability of sustainability information in mining companies in the ASEAN region.

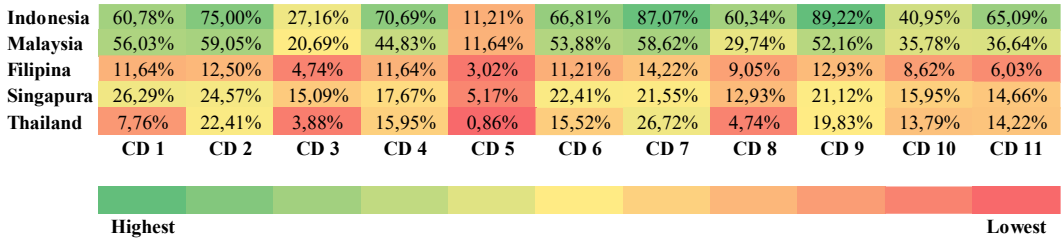
Carbon Disclosure Content Analysis Results



Source: Data processed by researchers using Excel, 2026

Figure 5. Percentage of Carbon Disclosure Indicators

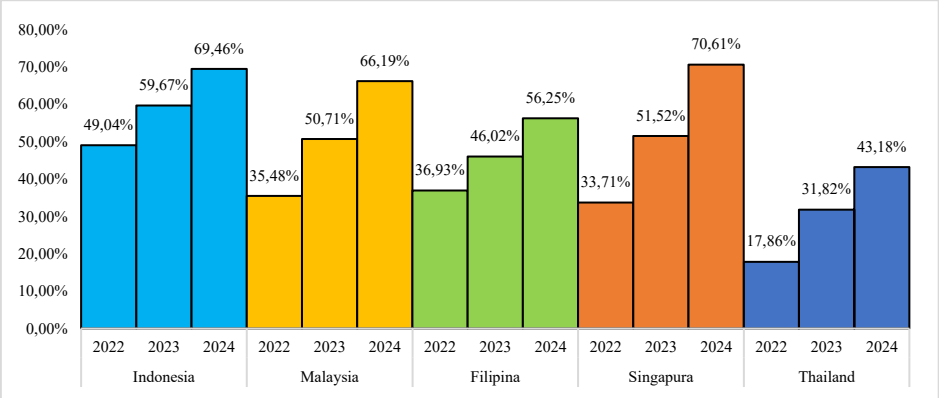
Figure 5 shows that mining companies in the five ASEAN countries tend to disclose more information related to climate risk management than to climate strategy aspects. Indicators with the highest levels of disclosure include Climate Risk Management (75.00%), Climate Risk and Opportunity Metrics (70.34%), and Management Role (69.72%), while the indicators for Climate Opportunity Identification (25.78%) and Climate Strategy Resilience (11.49%) show the lowest levels of disclosure. This finding indicates that companies are more prepared to disclose operational and governance information than to explain long-term strategies for addressing climate change. Overall, these results indicate that carbon disclosure practices in the ASEAN region still focus more on risk management aspects, while disclosures regarding climate opportunities and strategy resilience still need to be improved to make carbon reporting more comprehensive.



Source: Data processed by researchers using Excel, 2026

Figure 6. Heatmap of Carbon Disclosure Indicators

Figure 6 shows the variation in carbon disclosure levels across the five ASEAN countries. Indonesia and Malaysia demonstrate relatively higher levels of disclosure, particularly for the Climate Risk and Opportunity Metrics and Management Role indicators, while the Philippines and Thailand are more prominent in Climate Risk Management, and Singapore in Board Oversight. Conversely, Climate Strategy Resilience is the indicator with the lowest disclosure level across all countries, indicating that most companies have not adequately disclosed their business strategy capabilities in addressing various climate change scenarios. Overall, the content analysis results indicate that mining companies in the ASEAN region have shown progress in disclosing aspects of climate risk governance and management, but disclosures regarding long-term climate strategies remain relatively limited. Therefore, improving the quality of carbon reporting needs to focus on disclosing companies' strategies, opportunities, and resilience to climate change to provide more comprehensive information.



Source: Data processed by researchers using Excel, 2026

Figure 7. Average Carbon Disclosure Indicator

Figure 7 shows that the average carbon disclosure of mining companies across all sample countries increased during the 2022-2024 period. Singapore recorded the largest increase, at 36.90 percentage points, followed by Malaysia (30.71 points), Thailand (25.32 points), Indonesia (20.42 points), and the Philippines (19.32 points). Although all countries showed a positive trend, carbon disclosure levels varied, with Singapore having the highest disclosure level at the end of the observation period, while Thailand remained at the lowest. This finding indicates increasing transparency in carbon reporting across the ASEAN region. However, differences in regulation, governance, and stakeholder demands continue to cause uneven distribution of carbon disclosure quality and completeness across countries.

Chow Test Results

Table 9. Chow Test Results

Effects Test	Statistic	d.f.	Prob.
Cross-section F	4,9901	(112,204)	0,0000
Cross-section Chi-square	424,7182	112	**0,0000**

Source: Data Processed by Researchers with Eviews 9, 2026

Based on the results of the Chow Test, the probability value of the Cross-section F is 0.0000 and the Cross-section Chi-square is 0.0000, so both are smaller than the significance level of 0.05. These results indicate that H0 which states the Common Effect Model (CEM) is rejected, so H1 which states the Fixed Effect Model (FEM) is accepted and is more appropriate to use for this study, because there are differences in characteristics between mining companies in five ASEAN countries. Thus, the selection of the panel data regression model needs to be continued to the next stage through the Hausman Test to determine whether the Fixed Effect Model remains the best model or needs to be compared with the Random Effect Model. (Gujarati & Porter, 2009).

Hausman Test Results

Table 10. Hausman Test Results

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	88,6632	5	**0,0000**

Source: Data Processed by Researchers with Eviews 9, 2026

Based on the results of the Hausman Test, the probability value in the random Cross-section is 0.0000, so it is smaller than the significance level of 0.05. This result indicates that H0 which states the Random Effect Model (REM) is rejected, so H1 which states the Fixed Effect Model (FEM) is accepted and is more appropriate to be used in this study. Thus, the

panel data regression model used in this study is FEM, because the model is able to consider the differences in the characteristics of each mining company in the five ASEAN countries in analyzing the influence of independent variables on the dependent variable, in accordance with the stages of model selection in econometric analysis (Gujarati & Porter, 2009).

Hypothesis Test Results Analysis

Coefficient of Determination Test Results

Table 11. Coefficient of Determination Test Results

R-squared	0,3249
Adjusted R-squared	0,3142

Source: Data Processed by Researchers with Eviews 9, 2026

Based on the results of the coefficient of determination test, the R-squared value of 0.3249 indicates that the variables of sustainability assurance, board independence, institutional ownership, Gross Domestic Product, and company size are able to explain variations in carbon disclosure by 32.49%, while the Adjusted R-squared value of 0.3142 indicates that after adjusting for the number of variables in the model, the model's explanatory power becomes 31.42%. Thus, approximately 68.58% of the variation in carbon disclosure is still influenced by other factors outside this research model, such as regulatory pressure, corporate governance quality, industry characteristics, environmental risk levels, and sustainability policies of each company, so these results need to be understood critically because the coefficient of determination shows the strength of the model as well as the limits of the ability of independent variables to explain the dependent variable (Gujarati & Porter, 2009).

F-Test Results

Table 12. F-Test Results

F-statistic	30,4090
Prob(F-statistic)	0,0000

Source: Data Processed by Researchers with Eviews 9, 2026

Based on the results of the F-test, the F-statistic value of 30.4090 with a Prob(F-statistic) of 0.0000 indicates that the regression model used in this study is simultaneously significant, because the probability value is smaller than the significance level of 0.05. This result means that the variables of sustainability assurance, board independence, institutional ownership, Gross Domestic Product, and company size together have an influence on carbon disclosure in mining companies in five ASEAN countries. Thus, this research model is considered suitable for use to explain the relationship between variables, because the F-test functions to see whether all independent variables in the model are simultaneously able to explain changes in the dependent variable (Gujarati & Porter, 2009).

T-Test Results

Table 13. T-Test Results

Variables	Predicted Influence	Coefficient	t-Statistic	Prob.	Results
C	-	-1,7654	-2,7065	0,0072	-
X1	Positive and significant	0,6001	7,5556	0,0000	H1 Accepted
X2	Positive and insignificant	0,0717	0,7727	0,4403	H2 Rejected
X3	Positive and significant	0,1307	2,6808	0,0077	H3 Accepted
X4	Positive and insignificant	0,0284	1,1140	0,2661	H4 Rejected
X5	Positive and significant	0,0574	6,7320	0,0000	H5 Accepted

Source: Data Processed by Researchers with Eviews 9, 2026

Based on the t-test results in Table 13, Sustainability Assurance, Institutional Ownership, and Company Size have a positive and significant effect on Carbon Disclosure with probability values of 0.0000, 0.0077, and 0.0000, respectively ($p < 0.05$). These results indicate that the quality of sustainability assurance, high institutional ownership, and large company size can encourage increased transparency in carbon disclosure. In contrast, Board Independence ($p = 0.4403$) and Gross Domestic Product ($p = 0.2661$) show a positive but insignificant effect on Carbon Disclosure, so these two variables have not been statistically proven to influence the level of carbon disclosure in mining companies in five ASEAN countries. Thus, hypotheses H1, H3, and H5 are accepted, while H2 and H4 are rejected.

Discussion

The Effect of Sustainability Assurance on Carbon Disclosure

The results of this study indicate that sustainability assurance has a positive and significant effect on carbon disclosure in mining companies in five ASEAN countries. This finding indicates that the presence of assurance enhances the credibility of disclosed carbon information, enabling companies to convey more transparent and reliable environmental information. The content analysis also shows that companies with higher levels of sustainability assurance tend to present more complete, consistent, and verifiable information than companies that disclose only limited assurance elements. This is crucial for mining companies facing high environmental risks and growing accountability demands from investors, regulators, and the public.

These results align with the findings of Hazaea et al. (2022) and Suhardianto et al. (2026), which state that sustainability assurance serves as a mechanism to improve the quality and transparency of carbon disclosure. Furthermore, these findings support Legitimacy Theory, which explains that companies strive to gain and maintain social legitimacy through the delivery of credible and accountable environmental information. Thus, sustainability assurance not only serves as a complement to sustainability reports, but also becomes an important instrument in strengthening stakeholder trust in the company's commitment to managing environmental impacts.

The Effect of Board Independence on Carbon Disclosure

The results of this study indicate that board independence has a positive but insignificant relationship with carbon disclosure in mining companies in five ASEAN countries. This finding indicates that the presence of an independent board has not significantly encouraged companies to improve the transparency of their carbon disclosure. This suggests that carbon disclosure in mining companies is more influenced by other factors, such as regulatory pressure, investor demands, environmental risks, the availability of emissions data, and management's commitment to sustainability reporting. Therefore, the effectiveness of an independent board in encouraging carbon disclosure depends on the extent to which its oversight function is actively implemented and oriented towards environmental issues.

This finding differs from the research of Mansour et al. (2025), which found that board independence can improve carbon disclosure. However, it aligns with the views of Amegboleza et al. (2025) and Blay et al. (2024), which emphasize the importance of environmental competence and stronger governance mechanisms for independent boards to effectively carry out their oversight function. Furthermore, this study's results do not fully support Stakeholder Theory, as the presence of an independent board has not been shown to improve company responsiveness to stakeholders' carbon information needs. Thus, the role of independent boards in improving carbon disclosure needs to be supported by sustainability competencies, relevant committees, and the integration of climate change issues into the company's strategic oversight.

The Influence of Institutional Ownership on Carbon Disclosure

The results of this study indicate that institutional ownership has a positive and significant effect on carbon disclosure in mining companies in five ASEAN countries. This finding indicates that the greater the proportion of institutional ownership, the higher the level of transparency of a company's carbon disclosure. Institutional investors generally have stronger oversight capabilities and pay attention to long-term risks, including environmental, reputational, and sustainability risks, thus encouraging companies to disclose carbon information more openly. These results align with research by Kordsachia et al. (2022), Cohen et al. (2023), and Zuo et al. (2025), which shows that institutional investors play a role in improving the quality of carbon disclosure through more effective oversight mechanisms.

These findings also support Stakeholder Theory, which explains that companies need to meet the information needs of stakeholders, particularly institutional investors who consider sustainability aspects in their investment decisions. For mining companies, carbon disclosure serves as a form of accountability to investors, regulators, and the public for the environmental impacts of the company's operational activities. Thus, the presence of institutional investors is an important factor that encourages companies to improve the transparency and quality of carbon disclosure as part of sustainable governance practices.

The Influence of Gross Domestic Product on Carbon Disclosure

The results of this study indicate that Gross Domestic Product (GDP) has a positive but insignificant relationship with carbon disclosure among mining companies in five ASEAN countries. This finding indicates that a country's macroeconomic conditions are not yet a primary factor driving companies to increase their carbon disclosure transparency. Differences in carbon disclosure levels are more influenced by mining industry characteristics, regulatory pressures, investor demands, environmental risks, and the company's ability to manage and report emissions information than by the economic capacity of the country in which the company operates. These results align with research by Manjengwa et al. (2025) and Suhardianto et al. (2026), which shows that economic growth is not always accompanied by improvements in the quality of sustainability reporting.

These findings provide only limited support for Legitimacy Theory. Although countries with higher levels of economic development are expected to experience greater social and regulatory pressures for environmental transparency, the results indicate that mining companies' legitimacy is shaped more by their response to environmental risks, stakeholder demands, and commitment to carbon reporting than by national macroeconomic conditions. Thus, Gross Domestic Product is not the main determinant of carbon disclosure in mining companies in the ASEAN region.

The Effect of Company Size on Carbon Disclosure

The results of this study indicate that company size has a positive and significant effect on carbon disclosure in mining companies in five ASEAN countries. This finding indicates that larger companies tend to have higher levels of carbon disclosure due to the support of more adequate resources, reporting systems, and organizational capacity. Furthermore, larger companies face greater pressure from investors, regulators, the public, and the media, thus encouraging them to increase transparency in reporting environmental information. These results align with research by Bolibok et al. (2024) and Wang et al. (2026), which found that large companies have better carbon disclosure quality than smaller companies.

These findings suggest that internal company capacity is a critical factor in improving the quality of carbon disclosure. Larger mining companies have better capabilities in establishing emission measurement systems, preparing sustainability reports, and meeting stakeholders' information needs. These results are also consistent with the findings of Munir et al. (2025), Al-Mari et al. (2024), and Safas et al. (2026) emphasized that company scale contributes to increased environmental transparency. Therefore, companies with greater

resources and reporting capacity tend to be able to provide more comprehensive and high-quality carbon information as part of their risk management and sustainability accountability efforts.

CONCLUSION

Sustainability assurance has a positive and significant effect on carbon disclosure, thus H1 is accepted. These results indicate that the better the quality of sustainability assurance provided by a company, the higher the carbon disclosure. Therefore, sustainability assurance can be understood as a factor encouraging mining companies to be more transparent in disclosing carbon information to stakeholders.

Board independence has a positive but insignificant effect on carbon disclosure, therefore H2 is rejected. This finding indicates that the presence of an independent board is not strong enough to significantly encourage increased carbon disclosure, as carbon disclosure is not solely determined by board structure but is also influenced by company commitment, regulatory pressure, governance quality, and management awareness of climate change risks.

Institutional ownership has a positive and significant effect on carbon disclosure, therefore H3 is accepted. These results demonstrate that greater institutional ownership increases the incentive for companies to disclose carbon, as institutional ownership acts as an external oversight mechanism that strengthens corporate accountability on carbon issues.

Gross Domestic Product has a positive but insignificant effect on carbon disclosure, therefore H4 is rejected. These results indicate that a country's economic conditions are not a direct factor determining the extent of carbon disclosure by mining companies. Therefore, carbon disclosure by mining companies in ASEAN is more influenced by internal company factors and specific governance pressures than by the country's economic size directly.

Company size has a positive and significant effect on carbon disclosure, thus H5 is accepted. This finding suggests that mining companies with larger asset sizes tend to have greater capacity and pressure to disclose carbon information, making company size a significant factor reinforcing mining companies' tendency to increase carbon disclosure.

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