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Carbon Management Accounting, Profitability, and Carbon Tax Intensity: The Moderating Role of the Energy Mix

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ABSTRACT
The energy sector is the largest contributor to greenhouse gas emissions in Indonesia and is the first sector subject to the carbon tax under Law No. 7 of 2021 on the Harmonization of Tax Regulations. This study investigates the effect of Carbon Management Accounting (CMA) on profitability and carbon tax intensity, while examining the moderating role of the energy mix, measured by the consumption ratios of coal, diesel, and biodiesel. Unlike previous studies that proxy CMA using disclosure indices or PROPER ratings, this study measures CMA directly based on the quantification of Scope 1 carbon footprint using emission factors from the Intergovernmental Panel on Climate Change (IPCC) Tier 1 and Indonesia's Ministry of Energy and Mineral Resources (MEMR) Tier 2. The sample consists of six coal mining companies listed on the Indonesia Stock Exchange during the 2020–2024 period, yielding 30 firm-year observations selected through purposive sampling. The data were analyzed using Moderated Regression Analysis (MRA) based on a Fixed Effects Model with White cross-section robust standard errors in EViews 13. The results indicate that CMA has no significant effect on profitability, measured by Return on Equity (ROE), across all models ($p = 0.8133$, 0.3268, and 0.4930), and none of the three energy mix ratios moderates this relationship. In contrast, CMA has a significant positive effect on carbon tax intensity in both the diesel model ($\beta = 0.00138$, $p = 0.0026$) and the biodiesel model ($\beta = 0.00348$, $p = 0.0020$). Furthermore, all three energy mix ratios significantly moderate this relationship. The coal consumption ratio strengthens the positive effect of CMA on carbon tax intensity ($\beta = 0.00567$, $p = 0.0028$), whereas the diesel ($\beta = -0.00216$, $p = 0.0186$) and biodiesel ($\beta = -0.00348$, $p = 0.0059$) consumption ratios weaken it. These findings suggest that the benefits of CMA are more evident in reducing carbon tax exposure than in improving firms' short-term profitability.

Keywords: Carbon Management Accounting, Carbon Accounting, Profitability, Carbon Tax Intensity.
JEL Code: G30, H23, M41, Q56, L71

I. Introduction

Human-induced global warming has increased by approximately 1°C compared to the pre-industrial era and continues to rise alongside increasing greenhouse gas emissions. If global temperatures increase by 1.5°C to 2°C, the consequences are expected to be substantial across four critical areas: climate, ecosystems, food security, and human health. In Indonesia, the energy sector is the largest contributor to carbon dioxide emissions, surpassing the forestry, waste, and agriculture sectors. It accounts for approximately 34% of the country's total greenhouse gas emissions and is projected to contribute more than 58% by 2030 in the absence of significant decarbonization efforts. This situation has prompted the Indonesian government to issue Presidential Regulation No. 98 of 2021 on the Implementation of Carbon Economic Value as a framework for achieving the Nationally Determined Contribution (NDC), which was subsequently increased to 31.89% through domestic efforts and 43.20% with international support by 2030, alongside the national target of achieving Net Zero Emissions by 2060. In addition to this regulatory framework, the government seeks to reduce greenhouse gas emissions through economic instruments stipulated in Chapter VI, Article 13 of Law No. 7 of 2021 on the Harmonization of Tax Regulations, which establishes a minimum carbon tax rate of Rp30.00 per kilogram of carbon dioxide equivalent (CO_2e). The carbon tax is planned to be implemented gradually, beginning with coal-fired power plants (PLTU). Cross-country evidence suggests that effective environmental taxation internalizes environmental externalities and encourages behavioral change, although concerns regarding the distribution of tax burdens and industrial competitiveness remain unresolved (Sapiri, 2025). Furthermore, a general equilibrium simulation for Indonesia indicates that higher carbon tax rates may lead to greater welfare losses, highlighting the importance of establishing an accurate emissions database before implementing the policy (Andrianus et al., 2024). This context gives rise to the central dilemma addressed in this study. The carbon tax is imposed based on emissions information generated through a company's carbon accounting process. Therefore, more effective implementation of Carbon Management Accounting (CMA) is expected to enhance the effectiveness of carbon tax policy initiatives (Suswandoyo, 2024). However, studies examining the relationship between carbon tax policy and sustainability reporting in Indonesia indicate that integration between these two instruments remains limited because most sustainability reports still do not disclose quantitative emissions data or provide third-party verification (Firmansyah & Irawan, 2025). In addition, a bibliometric analysis of the carbon tax literature confirms that empirical studies in developing countries, particularly Indonesia, remain considerably fewer than those conducted in developed countries (Sulistiyanti U & Falikhatun F, 2024). Consequently, fiscal instruments intended to reduce emissions continue to rely largely on voluntarily disclosed corporate information.

Empirical evidence regarding the economic consequences of carbon accounting practices remains inconclusive. Several studies report that CMA has no significant effect on financial performance, suggesting that investors continue to prioritize traditional financial indicators and have not fully incorporated environmental considerations into their investment decisions (Mariyah et al., 2023; Suswandoyo, 2024; Taufiq et al., 2022). In contrast, other studies demonstrate that companies with higher carbon efficiency achieve superior short-term operational performance and gain competitive advantages in capital markets through systematic reductions in environmental risk (Trinks et al., 2020). Similarly, carbon emission disclosure has been found to positively influence firm value (Surianti et al., 2024) and financial performance (Rahmawati & Hartoko, 2024), while reductions in carbon emissions are positively associated with firm profitability (Oestreich & Tsiakas, 2024; Liu et al., 2023, as cited in Vaicondam et al., 2025). Conversely, other studies report negative or insignificant relationships, indicating that the economic benefits of carbon initiatives may require a longer period to be recognized by the market (Fina et al., 2024; Paradilla et al., 2025; Puspawati et al., 2026). These inconsistent findings may also be explained by differences in firm characteristics, including firm size (Bedi & Singh, 2024) and the characteristics of firms that disclose carbon-related information (Wayan Apriyani et al., 2026). This study argues that these inconsistencies also arise from limitations in the measurement of CMA. Previous studies have generally proxied CMA using dichotomous disclosure indices or the Ministry of Environment's PROPER rating. However, many components of these measures are not directly related to carbon emission sources, including corporate social responsibility, 3R (reduce, reuse, and recycle) practices, hazardous waste management, and biodiversity management. As a result, these proxies may introduce measurement bias when the objective is to examine the impact of carbon emissions on firm performance, because indicators unrelated to emissions are incorporated into measures intended to capture carbon management activities. Moreover, no previous study has directly estimated the projected carbon tax burden arising from a company's energy consumption profile and examined it as a separate dependent variable. Likewise, the moderating role of the energy mix has received limited attention, despite the fact that fuel selection represents a managerial decision that directly influences a company's carbon footprint.

Based on the issues discussed above, this study addresses four research questions: (1) Does Carbon Management Accounting affect firm profitability? (2) Does Carbon Management Accounting affect carbon tax intensity? (3) Do the coal, diesel, and biodiesel consumption ratios moderate the relationship between Carbon Management Accounting and firm profitability? and (4) Do the coal, diesel, and biodiesel consumption ratios moderate the relationship between Carbon Management Accounting and carbon tax intensity? Accordingly, this study aims to examine the direct effects of Carbon Management Accounting on profitability and carbon tax intensity among coal-mining companies listed on the Indonesia Stock Exchange during the 2020–2024 period. This study makes four primary contributions. First, it offers a methodological contribution by measuring CMA through the direct quantification of Scope 1 carbon emissions based on actual fuel consumption using emission factors published by the Intergovernmental Panel on Climate Change (IPCC) and Indonesia's Ministry of Energy and Mineral Resources (MEMR), thereby eliminating the influence of non-emission indicators. Second, it provides an empirical contribution by introducing carbon tax intensity as a dependent variable estimated ex ante using the carbon tax rate stipulated in Law No. 7 of 2021, enabling companies' potential carbon tax burdens to be assessed before production takes place. Third, it makes a theoretical contribution by demonstrating that institutional pressure and legitimacy influence firms primarily through fiscal mechanisms rather than through improvements in short-term profitability, as reflected in reductions in carbon tax burdens. Finally, this study offers a policy contribution by providing regulators with estimates of how carbon tax burdens may be distributed across companies with different energy mixes. The remainder of this article is organized as follows. Section II presents the literature review and hypothesis development. Section III describes the research methodology. Section IV presents the empirical results and discussion. Finally, Section V concludes the study and discusses its implications, limitations, and directions for future research.

II. Literature Review and Hypothesis Development

2.1. Conceptual Delimitation: Environmental Accounting, Carbon Accounting, Carbon Management Accounting, and Carbon Costing

The sustainability accounting literature often uses the terms environmental accounting, carbon accounting, Carbon Management Accounting (CMA), and carbon costing interchangeably, although these concepts differ in both scope and hierarchy. This terminological ambiguity makes it difficult to compare findings across studies because concepts described using the same terminology are often operationalized differently. Therefore, this section establishes the conceptual boundaries adopted throughout this study, as summarized in Table 1.

Table 1. Conceptual Delimitation of Key Terms

Term	Scope	Position in This Study	Key Reference
Environmental Accounting	The broadest umbrella concept, encompassing all environmental impacts, including emissions, waste, and biodiversity, within the accounting information system.	Not measured directly; serves as the disciplinary context.	Scaletti et al. (2025)
Carbon Accounting (CA)	The measurement, recording, and quantification of greenhouse gas emissions	Serves as the quantitative basis for the independent variable through the	Stechemesser & Guenther (2012)

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	throughout the value chain, including the assessment of their environmental impacts.	measurement of the Scope 1 carbon footprint.	
Carbon Management Accounting (CMA)	A managerial accounting system that integrates carbon accounting, carbon costing, emission reduction strategies, and carbon-related reporting to stakeholders.	Represents the study's primary construct and is operationalized through its emission quantification component (carbon accounting), which forms the core of the system.	Burritt et al. (2011); Sharaf-Addin (2024)
Carbon Costing / Carbon Tax	The CMA component that translates emission quantities into monetary consequences, including carbon tax liabilities.	Serves as the basis for constructing the second dependent variable, namely carbon tax intensity.	Gibassier & Schaltegger (2015); Heine et al. (2020)

Source: Processed by the authors (2026).

Based on this conceptual delimitation, this study positions Carbon Management Accounting as the overarching management system, carbon accounting as its measurement component, and carbon taxation as its costing component. Accordingly, references to the effect of CMA in this study specifically refer to the quality and outcomes of Scope 1 emission quantification, which represents the operational core of the system, rather than to an aggregate disclosure index. This distinction constitutes the primary methodological difference between the present study and previous research that has measured CMA using dichotomous disclosure indices or PROPER ratings.

2.2. Theoretical Foundation and Hypothesis Development

Production theory and cost theory provide the primary theoretical foundations for explaining the relationship between the energy mix and firm performance. Modern production theory no longer views production solely as the transformation of inputs into outputs but rather as a value creation process encompassing economic, social, and environmental dimensions (Dyckhoff, 2018). Within this framework, coal, diesel, and biodiesel represent production inputs that influence both operational efficiency and the emission profile of a company. Cost theory complements this perspective by explaining that production activities generate not only desirable outputs but also undesirable outputs, such as greenhouse gas emissions, waste, and other pollutants, collectively referred to as ecological costs. In the mining industry, these ecological costs include regulatory costs arising from carbon tax obligations, reputational costs associated with environmental performance, and long-term operational costs related to investments in low-emission technologies. Together, these theories provide the theoretical foundation for Hypotheses 1 and 2 by suggesting that differences in the composition of production inputs result in differences in ecological costs, which subsequently affect profitability and carbon tax intensity. Legitimacy theory explains why mining companies voluntarily disclose carbon emissions despite the absence of mandatory carbon disclosure requirements in Indonesia (Mariyah et al., 2023). Companies disclose emissions information to obtain legitimacy from society, regulators, and investors, thereby maintaining their social acceptance and enhancing their long-term financial performance (Qian & Schaltegger, 2017). Firms with superior performance are generally more likely to disclose carbon-related information as a signal of strong environmental performance and as a means of differentiating themselves from competitors.

Moreover, effective climate governance enhances the credibility of such disclosures (Bui et al., 2020; Ong et al., 2021). However, legitimacy theory also suggests the opposite possibility: firms with weaker environmental performance may disclose more information as a strategy to improve public perception and preserve organizational legitimacy. This dual perspective makes the direction of the relationship between CMA and profitability theoretically ambiguous. Consequently, although Hypothesis 1 predicts a negative relationship, the empirical validity of this prediction remains an open question. Institutional theory provides the theoretical basis for Hypothesis 2 and the moderating hypotheses. According to institutional theory, companies adopt environmental management accounting practices not solely because of internal awareness but also in response to external institutional pressures. These pressures include coercive pressures arising from government regulations, normative pressures originating from professional standards, and mimetic pressures resulting from the tendency to imitate organizations perceived as successful (Powell & DiMaggio, 2023). Consequently, the widespread adoption of environmental accounting practices within an industry is not always driven by economic efficiency alone. In the Indonesian context, coercive institutional pressure operates progressively, beginning with emission thresholds established by the Ministry of Energy and Mineral Resources and the Ministry of Environment and Forestry, and extending to the planned implementation of a carbon tax by the Ministry of Finance. Because coercive pressure is ultimately translated into fiscal obligations that are calculated directly from the quantity of emissions produced, institutional theory predicts that the relationship between CMA and carbon tax intensity will be stronger than the relationship between CMA and profitability, the latter being influenced indirectly through market perceptions and investor responses. This theoretical prediction forms the central proposition tested in the present study.

2.3. Carbon Management Accounting and Profitability

Profitability in this study is measured using Return on Equity (ROE), defined as the ratio of net income available to common shareholders to common shareholders' equity. ROE was selected because most previous studies have employed Return on Assets (ROA), which primarily reflects the efficiency of asset utilization. In contrast, given the government's implementation of carbon tax regulations, the impact of carbon emission management should be evaluated from the shareholders' perspective, specifically by examining the extent to which carbon efficiency contributes to shareholder returns and how investors respond to environmentally responsible corporate performance. Accordingly, this study does not focus on the absolute level of ROE but rather on whether Carbon Management Accounting (CMA) significantly influences ROE. Previous empirical findings remain inconclusive. A study of mining companies listed on the Indonesia Stock Exchange found that CMA, measured using the PROPER rating, had no significant effect on financial performance (Taufiq et al., 2022). Likewise, CMA measured using a dichotomous disclosure index was found to have no significant effect on firms' market performance because of the limited disclosure of the four CMA indicators (Suswandoyo, 2024). Similar results were reported for manufacturing companies, where carbon accounting did not significantly affect profitability (Mariyah et al., 2023). In contrast, a study of 1,572 companies across 47 countries using the Directional Distance Function and Data Envelopment Analysis (DEA) approach found that firms with higher carbon efficiency achieved superior short-term profitability (Trinks et al., 2020). Similarly, carbon emission disclosure has been shown to improve financial performance among mining and energy companies (Rahmawati & Hartoko, 2024), while more recent cross-country evidence reports a positive association between carbon emission reductions and firm profitability (Oestreich & Tsiakas, 2024). In the context of Indonesian coal-mining companies, implementing CMA requires substantial expenditures, including costs associated with emission inventories, data verification, and investments in low-emission technologies, whereas the legitimacy benefits generated by these initiatives are generally realized only in the long term. Consistent with cost theory, when these expenditures are not immediately followed by higher revenues, they reduce the profits available to shareholders. Based on this reasoning, the first hypothesis is formulated as follows:

H1: Carbon Management Accounting has a significant negative effect on profitability.

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2.4. Carbon Management Accounting and Carbon Tax Intensity

Article 13(1) of Law No. 7 of 2021 stipulates that a carbon tax is imposed on carbon emissions that adversely affect the environment and that its implementation should be aligned with the Carbon Roadmap, one of whose key components is the Carbon Emission Reduction Strategy. This strategy is closely linked to the role of carbon accounting in designing a more efficient energy-use composition. An estimate of the government's potential carbon tax revenue based on energy-sector emissions demonstrates that the measurement and reporting of carbon emissions provide the basis for determining the carbon tax burden that companies may incur (Pratama et al., 2022). However, studies examining the integration of carbon tax policy with sustainability reporting indicate that most sustainability reports in Indonesia still do not disclose quantitative emissions data or provide third-party verification (Firmansyah & Irawan, 2025). Unlike the relationship between CMA and profitability, which is mediated by market perceptions, the relationship between CMA and carbon tax intensity is more direct and mechanical. The quantity of reported emissions is multiplied by the applicable carbon tax rate to determine the tax liability, which is subsequently divided by total revenue to obtain a measure of carbon tax intensity. Consistent with institutional theory, coercive institutional pressure operates directly through this fiscal mechanism. If CMA is not effectively implemented to reduce emissions, the emissions base used to calculate the carbon tax is expected to increase, thereby increasing the carbon tax burden relative to company revenue. Based on this reasoning, the second hypothesis is formulated as follows:

H2: Carbon Management Accounting has a significant positive effect on carbon tax intensity.

2.5. Energy Mix as a Moderating Variable

The energy mix is incorporated as a moderating variable because fuel selection represents a strategic managerial decision within the Carbon Management Accounting system that influences the emission profile of a company without altering the measured quantity of emissions used as the independent variable. In other words, the energy mix determines the extent to which each unit of carbon emissions translates into economic consequences. Coal has the highest emission factor, followed by diesel fuel. In contrast, the biogenic component of biodiesel is not included in Scope 1 carbon emissions; therefore, its emissions must be distinguished from those associated with the fossil diesel component in blended fuels. The GHG Protocol specifies that direct carbon dioxide emissions resulting from biomass combustion, including biofuels, are excluded from Scope 1 emissions but must still be disclosed separately. These differences in emission factors provide the theoretical basis for the moderating role of the energy mix. From a profitability perspective, companies that rely more heavily on fossil fuels incur higher environmental costs because of their greater carbon emissions. Consequently, the negative relationship between CMA and profitability is expected to become stronger. Conversely, companies that increasingly substitute fossil fuels with biodiesel are expected to reduce emission-related costs while enhancing their environmental reputation, thereby strengthening the positive contribution of CMA to profitability. With respect to carbon tax intensity, the mechanism is more straightforward. A higher proportion of fuels with high emission factors results in a larger carbon tax liability for each additional unit of emissions. Based on this reasoning, the third and fourth hypotheses are formulated separately for each fuel type as follows:

H3a: The coal-use ratio moderates the relationship between Carbon Management Accounting and profitability.
H3b: The diesel-use ratio moderates the relationship between Carbon Management Accounting and profitability.
H3c: The biodiesel-use ratio moderates the relationship between Carbon Management Accounting and profitability.

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H4a : The coal-use ratio moderates the relationship between Carbon Management Accounting and carbon tax intensity.

H4b : The diesel-use ratio moderates the relationship between Carbon Management Accounting and carbon tax intensity.

H4c : The biodiesel-use ratio moderates the relationship between Carbon Management Accounting and carbon tax intensity.

The six sub-hypotheses presented above represent two broader moderation hypotheses (H3 and H4), each of which is tested separately for the three fuel types. This approach is necessary because the coal, diesel, and biodiesel consumption ratios are mutually substitutive and collectively sum to one. Consequently, including all three ratios simultaneously in a single regression model would create multicollinearity. A detailed explanation of this modeling decision is provided in the Research Method section.

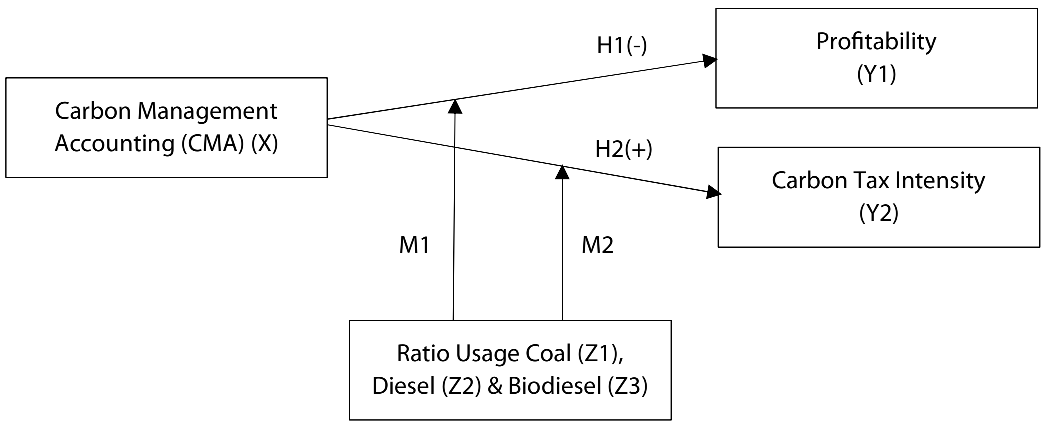

Figure 1. Conceptual Framework

III. Research Method

3.1. Research Design

This study employs a causal-explanatory research design using a quantitative approach and secondary data in the form of a balanced panel dataset. A causal-explanatory design was selected because the primary objective of the study is to examine the causal relationships among the variables rather than merely to describe their associations. The unit of analysis is the firm-year observation, with companies representing the cross-sectional dimension and fiscal years representing the time dimension. One important feature of the research design is the ex ante nature of the carbon tax intensity variable. Because the carbon tax had not yet been fully implemented during the observation period, the carbon tax liability was estimated through a policy simulation based on the minimum tax rate stipulated by law. Accordingly, this study does not measure the actual carbon tax paid by companies but instead estimates the potential fiscal exposure that companies would face if the carbon tax were implemented at the statutory minimum rate.

3.2. Population, Sample Selection Procedure, and Sample Size Justification

The population of this study comprises energy-sector companies listed on the Indonesia Stock Exchange (IDX). The sample was selected using a non-probability sampling technique with purposive sampling, whereby companies were chosen based on predefined criteria that aligned with the objectives of the study. The sample selection process was conducted in several stages, as presented in Table 2.

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Table 2. Sample Selection Procedure

No.	Description	Number of Companies
1	Energy-sector companies listed on the Indonesia Stock Exchange (IDX) in the Oil, Gas, and Coal Subsector	89
2	Companies operating in the Coal Production and Coal Distribution Subindustry	44
Exclusion criteria:		
3	Companies that did not publish complete sustainability reports for the 2020–2024 period	(33)
4	Companies that did not report total energy consumption and total carbon emissions for the 2020–2021 period	(3)
5	Companies whose business activities did not match the study criteria (i.e., companies not engaged in coal production and coal distribution)	(2)
Final sample of companies		6
Observation period (years)		5
Total firm-year observations		30

Source: Processed by the authors (2026).

The six companies that satisfied the sampling criteria are Alamtri Resources Indonesia Tbk (ADRO), Bumi Resources Tbk (BUMI), Dian Swastatika Sentosa Tbk (DSSA), Indo Tambangraya Megah Tbk (ITMG), Bukit Asam Tbk (PTBA), and TBS Energi Utama Tbk (TOBA). It should be emphasized that the relatively small sample size was not the result of an intentional restriction imposed by the researchers but rather reflected the limited availability of suitable data. Of the 44 companies in the coal subindustry, only six consistently disclosed fuel consumption by fuel type in convertible energy units and reported total carbon emissions quantitatively for five consecutive years. Moreover, these companies represent the largest coal issuers in Indonesia in terms of market capitalization. Therefore, despite the limited sample size, they account for a substantial share of the industry's production and emissions, making them broadly representative of the coal subindustry examined in this study. The 2020–2024 observation period was selected for three reasons. First, it covers the initial years following the mandatory implementation of sustainability reporting for listed companies under Article 10 of Financial Services Authority Regulation No. 51/POJK.03/2017, thereby ensuring the consistent availability of emissions data. Second, 2024 represents the most recent fiscal year for which sustainability reports had been fully published when this study was conducted. Third, the observation period encompasses a complete coal price cycle from 2020 to 2024, allowing variations in firm profitability to reflect conditions across an entire commodity cycle rather than a single phase of the market.

3.3. Data Collection and Verification Procedure

The data collection process was conducted in seven replicable stages. In the first stage, the list of sector, subsector, and subindustry classifications was obtained from the official website of the Indonesia Stock Exchange (IDX) to identify the study population. In the second stage, the annual reports and sustainability reports of each company were downloaded from the respective companies' official websites. Whenever discrepancies existed between document versions, the reports available on the Indonesia Stock Exchange website were used for verification. In the third stage, fuel consumption data by fuel type were extracted from the energy disclosure section of each sustainability report together with their original measurement units, which varied between gigajoules (GJ) and terajoules (TJ). In the fourth stage, all energy consumption values were converted into terajoules to ensure comparability across companies and fuel types. The fifth stage involved data verification. The converted energy consumption values for each fuel type were aggregated and compared with the total energy consumption reported by each company in the corresponding sustainability report. A similar verification procedure was applied to carbon emissions. The re-quantified emissions were

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compared with the total reported Scope 1 emissions to ensure that no systematic conversion errors had occurred. For companies reporting emissions generated from coal sales to third parties, those emissions were excluded so that only emissions arising from activities owned and controlled by the company were included in the analysis. In the sixth stage, financial data, including net income, shareholders' equity, and total revenue, were collected from the audited financial statements for the corresponding fiscal year. Finally, in the seventh stage, all data were compiled in Microsoft Excel 2021, cross-checked to minimize data-entry errors, and subsequently exported to EViews 13 for statistical analysis.

3.4. Variable Operationalization and Measurement

The independent variable, Carbon Management Accounting (CMA), is proxied by the total re-quantified Scope 1 carbon emissions. Scope 2 emissions are excluded because they represent indirect emissions associated with purchased electricity, while Scope 3 emissions are excluded because they are not consistently reported by all sample companies. Carbon emissions were estimated using two emission factor approaches: Tier 1, which applies the default emission factors published by the Intergovernmental Panel on Climate Change (IPCC), and Tier 2, which uses the national emission factors issued by Indonesia's Ministry of Energy and Mineral Resources (MEMR). Tier 3 emission factors were not applied because only a small number of companies reported the detailed operational data required for their calculation. The total carbon emissions were calculated as follows:

$$Total\ Emissions\ (TonCO_2\,e) = \ Fuel\ Consumptions\ (TJ) x\ \ IPCC/ESDM\ Emission\ Factor\ (Ton/TJ)$$

The carbon emissions estimated using the Tier 1 and Tier 2 approaches were averaged for each fuel type and then summed to obtain the total Scope 1 carbon emissions used in this study. The resulting value was transformed using the natural logarithm to reduce heteroscedasticity and stabilize the variance arising from substantial differences in emission levels across companies. Special treatment was applied to biodiesel. According to the GHG Protocol, direct CO_2 emissions from biomass combustion, including biofuels, are excluded from Scope 1 emissions but must be reported separately. Therefore, the biodiesel blend was first separated into its fossil diesel and biofuel components according to the applicable blending ratio. For example, under the B30 standard, only the fossil diesel component (70%) is included in the Scope 1 emissions calculation, whereas the biodiesel component (30%) is reported separately. The emission factors used in this study are presented in Table 3.

Table 3. Emission Factors Used for Carbon Emission Quantification

Fuel Type	Tier 1 – IPCC (tCO_2e/TJ)	Tier 2 – MEMR (tCO_2e/TJ)	Assumed Fuel Category
Coal	96.100	99.718	Sub-bituminous coal
Diesel	74.100	74.067	Industrial diesel oil
Biodiesel (B100/FAME)	70.800	Not available	Liquid biofuel (biodiesel)

Source: IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy; Guidelines for Greenhouse Gas Emission Inventories in the Energy Sector, Ministry of Energy and Mineral Resources (MEMR); processed by the authors (2026).

The fuel category assumptions presented in Table 3 were applied consistently across all sample companies because only one company explicitly disclosed the type of coal used, while none specified the type of diesel fuel consumed. The selection of the Industrial Diesel Oil category was based on the operating characteristics of heavy mining equipment. This assumption constitutes one of the limitations of the present study and is discussed further in the conclusion section. The first dependent variable, profitability, is measured using Return on Equity (ROE), calculated as follows:

$$ROE = \frac{Profit\ Available\ to\ Common\ Shareholders}{Common\ Shareholders'\ Equity}$$

The second dependent variable, Carbon Tax Intensity (CTI), is calculated by multiplying the total quantified emissions under each emission-factor approach by the statutory carbon tax rate of Rp30,000 per tonne of CO_2e. The Tier 1 and Tier 2 estimates are then averaged and divided by total company revenue for the corresponding fiscal year. Total revenue is used as the denominator to measure the relative carbon tax burden rather than its absolute monetary value.

$$CTI = \frac{(Tier\ 1\ Carbon\ Tax\ +\ Tier\ 2\ Carbon\ Tax) \div 2}{Total\ Revenue}$$

The moderating variable, the energy mix ratio, is measured as the proportion of energy consumption from each fuel type relative to the total energy consumption of coal, diesel, and biodiesel, with all energy values expressed in terajoules (TJ).

$$Coal\ Consumption\ Ratio\ (\%) = \frac{Fuel\ Consumptions\ Coal\ (TJ)}{Total\ Fuel\ Consumptions(TJ)\ Coal\ +\ Diesel\ +\ Biodiesel}$$

$$Diesel\ Consumption\ Proxy\ (\%) = \frac{Fuel\ Consumptions\ Diesel\ (TJ)}{Total\ Fuel\ Consumptions(TJ)\ Coal\ +\ Diesel\ +\ Biodiesel}$$

$$Biodiesel\ Consumption\ Proxy\ (\%) = \frac{Fuel\ Consumptions\ Biodiesel\ (TJ)}{Total\ Fuel\ Consumptions(TJ)\ Coal\ +\ Diesel\ +\ Biodiesel}$$

3.5. Model Specification and Justification of the Six Analytical Models

This study estimates six regression models. These models do not represent six independent analyses but are derived from the combination of two dependent variables and three moderating variables. The models are estimated separately for each moderator because including all three moderating variables simultaneously in a single regression model results in a near-singular matrix. Substantively, this issue arises because the three energy-mix ratios are mutually substitutive and collectively sum to one for each observation. Consequently, an increase in the proportion of one fuel type automatically reduces the proportions of the other two fuel types. Including all three ratios simultaneously therefore creates perfect linear dependence, leading to severe multicollinearity. Estimating separate models for each moderator is more appropriate because it isolates the moderating effect of each energy source, produces more stable parameter estimates, and facilitates the interpretation of which type of fuel contributes most strongly to the company's economic outcomes. The specifications of the six regression models are presented in Table 4.

Table 4. Regression Model Specifications

Dependent Variable	Moderator	Equation
ROE	Coal (COL)	$ROE = \beta 0 + \beta_1 Log(CMA) + \beta_2 COL + \beta_3 (Log(CMA) \times COL) + e$
ROE	Diesel (DSL)	$ROE = \beta 0 + \beta_1 Log(CMA) + \beta_2 DSL + \beta_3 (Log(CMA) \times DSL) + e$
ROE	Biodiesel (BIO)	$ROE = \beta 0 + \beta_1 Log(CMA) + \beta_2 BIO + \beta_3 (Log(CMA) \times BIO) + e$
CTI	Coal (COL)	$CTI = \beta 0 + \beta_1 Log(CMA) + \beta_2 COL + \beta_3 (Log(CMA) \times COL) + e$
CTI	Diesel (DSL)	$CTI = \beta 0 + \beta_1 Log(CMA) + \beta_2 DSL + \beta_3 (Log(CMA) \times DSL) + e$
CTI	Biodiesel (BIO)	$CTI = \beta 0 + \beta_1 Log(CMA) + \beta_2 BIO + \beta_3 (Log(CMA) \times BIO) + e$

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3.6. Estimation Model Selection and Testing Procedure

Panel data regression can be estimated using three alternative approaches: the Common Effects Model (CEM), the Fixed Effects Model (FEM), and the Random Effects Model (REM). The Common Effects Model pools cross-sectional and time-series observations without accounting for differences across individual entities. The Fixed Effects Model incorporates entity-specific effects that are assumed to remain constant over time, whereas the Random Effects Model treats individual effects as random variables that are assumed to be uncorrelated with the explanatory variables. The selection between the Fixed Effects Model and the Random Effects Model is commonly based on the Hausman test. However, in the present study, the Hausman test could not be reliably estimated because the panel consists of only six cross-sectional units, resulting in an unstable covariance matrix and unreliable Random Effects estimates. Consequently, the Fixed Effects Model was selected because it is conceptually more appropriate for panels with a small number of cross-sectional units and a relatively short observation period. Furthermore, the Fixed Effects Model effectively controls for unobserved heterogeneity across companies, including differences in mining technology, ownership structure, and concession locations. To address potential heteroskedasticity and partial serial correlation, all models were estimated using White cross-section robust standard errors. Before estimating the moderation models, a series of classical assumption tests was conducted. The normality of the residuals was assessed using the Jarque–Bera test, where a p-value greater than 0.05 indicates that the residuals are normally distributed. Multicollinearity was evaluated using the correlation matrix among the explanatory variables. Correlation coefficients below 0.50 indicate low multicollinearity, values between 0.50 and 0.80 indicate moderate multicollinearity, and values exceeding 0.80 indicate high multicollinearity. Heteroskedasticity was addressed using White cross-section robust standard errors in EViews. A statistically significant probability value ($p < 0.05$) indicates the presence of heteroskedasticity in the original residuals. Autocorrelation was assessed using the Durbin–Watson statistic, with values between 1.5 and 2.5 indicating the absence of serious autocorrelation. Hypothesis testing was conducted using the coefficient of determination (Adjusted R^2), the F-test for overall model significance, and the t-test for individual regression coefficients, all evaluated at the 5% significance level. A moderating effect is considered statistically supported when the coefficient of the interaction term is significant at the 5% level. The sign of the interaction coefficient indicates whether the moderating variable strengthens or weakens the relationship between the independent and dependent variables.

3.7. Software and Statement on the Use of Artificial Intelligence

The initial stages of data collection and processing were conducted using Microsoft Excel 2021, whereas all statistical analyses were performed using EViews 13. EViews was selected because it is specifically designed for panel data analysis, allowing the simultaneous estimation of cross-sectional and time-series data while providing the White cross-section robust standard error estimator required in this study. In accordance with the journal's policy on the use of artificial intelligence (AI), the authors declare that the research design, problem formulation, data collection, carbon emission quantification, statistical estimation, interpretation of the findings, and all scientific arguments presented in this article are entirely the authors' original work. AI-based tools were used solely to assist with language editing and consistency checking. All AI-generated suggestions were carefully reviewed, verified, and revised manually by the authors before being incorporated into the manuscript.

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IV. Results and Discussion

4.1. Descriptive Statistics

Descriptive statistics for all study variables are presented in Table 5. This analysis provides an overview of the distribution and characteristics of each variable before proceeding to the regression analysis.

Table 5. Descriptive Statistics (N = 30)

Variable	N	Minimum	Maximum	Mean	Standard Deviation
CMA (ln Scope 1 Emissions)	30	9.45716	15.06210	13.53637	1.17906
Profitability (ROE)	30	−0.05452	0.58707	0.18541	0.14964
Carbon Tax Intensity (CTI)	30	0.00008	0.00895	0.00207	0.00267
Coal Ratio (COL)	30	0.00000	0.97818	0.18497	0.30677
Diesel Ratio (DSL)	30	0.00000	0.78386	0.23734	0.34335
Biodiesel Ratio (BIO)	30	0.02129	1.00000	0.57768	0.37417

Source: EViews 13 output, processed by the authors (2026).

The CMA variable ranges from a minimum value of 9.45716 for TOBA in 2020 to a maximum value of 15.06210 for BUMI in 2023. The standard deviation is considerably lower than the mean, indicating that the distribution of carbon emissions is relatively stable after the logarithmic transformation. Profitability (ROE) ranges from −0.05452 for DSSA in 2020 to 0.58707 for ITMG in 2022, reflecting the impact of fluctuations in coal prices during the observation period. One extreme observation, namely BUMI's ROE of −2.633716 in 2020, was treated using winsorization at the 5th percentile, resulting in an adjusted value of −0.02824 to prevent the outlier from exerting an excessive influence on the regression estimates. Carbon tax intensity exhibits a standard deviation (0.00267) that exceeds its mean (0.00207), indicating substantial variation across companies. This variation reflects differences in both emission profiles and revenue levels among the sampled mining companies. The energy-mix ratios also reveal considerable differences in fuel-use strategies. A coal consumption ratio of zero is observed for DSSA, PTBA, and TOBA in certain years because these companies did not report coal as an operational fuel during those periods. Likewise, a diesel consumption ratio of zero is observed for ADRO, ITMG, PTBA, and TOBA because all reported diesel fuel consumption was in the form of biodiesel blends. The biodiesel ratio ranges from a minimum of 0.02129 for TOBA in 2021 to a maximum of 1.00000 for PTBA during 2023–2024, indicating that all liquid fuel consumed by the company during those years consisted of biodiesel blends in accordance with the government's mandatory biodiesel policy.

4.2. Correlation Analysis

The Pearson correlation matrix presented in Table 6 summarizes the direction and strength of the linear relationships among the study variables before conducting the regression analysis. It should be noted that correlation analysis identifies associations between variables but does not establish causal relationships.

Table 6. Pearson Correlation Matrix

Variable	CMA	ROE	CTI	COL	DSL	BIO
CMA (ln Scope 1 emissions)	1,00000					
Profitability (ROE)	−0,24739	1,00000				
Carbon Tax Intensity (CTI)	0,62200	−0,47579	1,00000			
Coal Ratio (COL)	0,24129	−0,19068	0,66115	1,00000		
Diesel Ratio (DSL)	0,29215	−0,37554	0,10897	−0,34174	1,00000	
Biodiesel Ratio (BIO)	−0,46591	0,50093	−0,64204	−0,50627	−0,63744	1,00000

Source: EViews 13 output, processed by the authors (2026).

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All pairwise correlation coefficients are below the conventional threshold of 0.80, indicating that the explanatory variables provide distinct information and that severe multicollinearity is unlikely to be a concern. Two notable patterns emerge from the correlation matrix. First, the correlation between CMA and carbon tax intensity (0.62200) is substantially stronger than the correlation between CMA and profitability (–0.24739). This finding suggests that carbon emissions are more closely associated with firms' potential fiscal exposure than with their financial performance. Second, the biodiesel consumption ratio is positively correlated with profitability (0.50093) and negatively correlated with carbon tax intensity (–0.64204), whereas the coal consumption ratio exhibits the opposite pattern. These results are consistent with the differences in carbon emission factors across fuel types, whereby biodiesel generally generates lower carbon emissions than coal.

4.3. Classical Assumption Test Results

A summary of the classical assumption test results for the six regression models is presented in Table 7.

Table 7. Summary of Classical Assumption Test Results

Model	Normality (Jarque–Bera p-value)	Multicollinearity (Maximum Correlation Between Predictors)	Heteroskedasticity (p-value)	Autocorrelation (Durbin–Watson)
ROE–COL	0.81338 (Normal)	0.24129 (between the main variables)	0.1797; 0.2657 (Not detected)	1.81735 (No indication)
ROE–DSL	0.83343 (Normal)	0.29215 (between the main variables)	0.8293; 0.3363 (Not detected)	1.91405 (No indication)
ROE–BIO	0.74484 (Normal)	–0.46591 (between the main variables)	0.0692; 0.0015 (Detected for the period effect)	1.77749 (No indication)
CTI–COL	0.00020 (Not normal)	0.24129 (between the main variables)	0.0000; 0.2715 (Detected for the cross-sectional effect)	1.54332 (No indication)
CTI–DSL	0.21171 (Normal)	0.29215 (between the main variables)	0.0000; 0.0048 (Detected for both cross-sectional and period effects)	1.09752 (Positive autocorrelation indicated)
CTI–BIO	0.31530 (Normal)	–0.46591 (between the main variables)	0.0000; 0.0042 (Detected for both cross-sectional and period effects)	1.11626 (Positive autocorrelation indicated)

Source: EViews 13 output, processed by the authors (2026).

All models with profitability as the dependent variable satisfy the classical regression assumptions. In contrast, three issues should be noted for the carbon tax intensity models. First, the residuals of the CTI–COL model are not normally distributed, as indicated by the Jarque–Bera test ($p = 0.00020$). The distribution exhibits a kurtosis value of 6.54703, suggesting the presence of an observation with substantially higher carbon tax intensity than the rest of the sample. Nevertheless, the analysis was continued because, according to the Central Limit Theorem, ordinary least squares (OLS) estimates remain unbiased and consistent even when the normality assumption is violated. Second, all CTI models exhibit evidence of heteroskedasticity. To

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address this issue, all regressions were estimated using White cross-section robust standard errors, thereby producing heteroskedasticity-robust coefficient estimates and statistical inference. Third, the CTI–DSL and CTI–BIO models show indications of positive autocorrelation based on their Durbin–Watson statistics. Such a pattern is common in panel data because observations are repeatedly collected from the same firms over time. In this study, the presence of autocorrelation is acknowledged as a limitation. No additional correction was applied beyond the use of robust standard errors. A separate note is warranted regarding the multicollinearity assessment. Although the correlation between the main explanatory variables remains well below the conventional threshold of 0.80, the correlation between each moderating variable and its corresponding interaction term is extremely high, reaching 0.99873 in the coal model, 0.99721 in the diesel model, and 0.98450 in the biodiesel model. This pattern is a well-known characteristic of Moderated Regression Analysis (MRA), as the interaction term is mathematically constructed from the product of the independent variable and the moderator. Consequently, this high correlation is not considered evidence of problematic multicollinearity. The interpretation therefore focuses on the significance of the interaction coefficient rather than on the coefficients of its component variables. Nevertheless, because this study did not apply mean-centering before constructing the interaction terms, the coefficients of the main effects should be interpreted as the effects of the independent variable when the moderator equals zero. Future studies are encouraged to apply mean-centering to improve coefficient interpretability.

4.4. Profitability Model Estimation Results

The estimation results for the three regression models with profitability (ROE) as the dependent variable are presented in Table 8.

Table 8. Profitability Model Estimation Results (Dependent Variable: ROE)

Variable	ROE–COL Coef.	Prob.	ROE–DSL Coef.	Prob.	ROE–BIO Coef.
Constant	0,36633	—	–1,09802	—	0,10117
CMA	–0,01510	0,8133	–0,00813	0,3268	0,02113
Moderator (Z)	1,65714	0,2739	3,03365	0,3442	1,04599
CMA × Z (interaction)	–0,10936	0,3168	0,20241	0,2483	–0,10577
Adjusted R^2	0,17558	Low	0,25702	Low	0,40946
Prob (F-statistic)	0,13997	Not significant	0,06490	Not significant	0,12956

Source: EViews 13 output, processed by the authors (2026).

4.5. Carbon Tax Intensity Model Estimation Results

The estimation results of the three regression models, with carbon tax intensity as the dependent variable, are presented in Table 9.

Table 9. Carbon Tax Intensity Model Estimation Results (Dependent Variable: CTI)

Variable	CTI–COL Coef.	Prob.	CTI–DSL Coef.	Prob.	CTI–BIO Coef.	Prob.
Constant	0,00530	—	–0,01385	—	–0,04321	—
CMA	–0,00034	0,1114	0,00138	0,0026***	0,00348	0,0020***
Moderator (Z)	–0,07185	0,0031***	0,01886	0,7182	0,04269	0,0069***
CMA × Z (interaction)	0,00567	0,0028***	–0,00216	0,0186**	–0,00348	0,0059***
Adjusted R^2	0,91318	Strong	0,82328	Strong	0,85649	Strong
Prob (F-statistic)	0,00000	Significant	0,00000	Significant	0,00000	Significant

Source: EViews 13 output, processed by the author (2026). *** Significant at the 1% level; ** significant at the 5% level.

4.6. Discussion

a. The Effect of CMA on Profitability

The t-test results indicate that CMA has no significant effect on profitability in any of the three models, with probability values of 0.8133, 0.3268, and 0.4930, respectively, all of which exceed the 5% significance threshold. This finding is further supported by the low to moderate Adjusted R^2 values, ranging from 0.17558 to 0.40946, as well as insignificant F-test results across all three models. Therefore, Hypothesis H1, which states that CMA has a significant negative effect on profitability, is rejected. Several explanations may account for this insignificant relationship. First is the commodity price dominance mechanism. The profitability of coal companies during the 2020–2024 period was largely determined by fluctuations in global coal prices, whose impact substantially exceeded the variation in costs associated with carbon management. The relatively low Adjusted R^2 values are consistent with this explanation, indicating that most of the variation in ROE is explained by factors outside the model. Second is the absence of an effective carbon pricing mechanism. During the observation period, the carbon tax had not yet been implemented, meaning that no actual cash outflows linked emissions directly to corporate profits. Without an explicit carbon price, emissions remained an externality that had not been internalized, which is consistent with the polluter-pays principle underlying Pigouvian taxation (Heine et al., 2020). Third is the asymmetry in the investment time horizon. Investments in carbon management, such as emission inventory systems, third-party verification, and the renewal of low-emission fleets, are recognized as current-period expenses, whereas their benefits in terms of operational efficiency and corporate legitimacy are typically realized over a longer period. Consequently, a contemporaneous analysis within a single fiscal year is unlikely to capture these long-term benefits. Collectively, these mechanisms suggest that carbon management currently influences firm performance indirectly through other variables, such as carbon tax exposure, rather than directly through the profitability channel.

Compared with previous studies, this finding both supports and extends the literature reporting that CMA has no significant effect on financial performance (Taufiq & Pratiwi, 2022; Suswandoyo, 2024; Mariyah et al., 2023). The contribution of this study lies in its measurement approach. While those studies rely on disclosure indices or PROPER ratings as proxies for carbon management, this study employs a physical emissions-based measure that is independent of non-emission indicators and still finds no significant relationship. These results suggest that the insignificant relationship between CMA and profitability is not attributable to measurement limitations but instead reflects the structural characteristics of the market. Conversely, this finding differs from studies reporting a positive effect of carbon efficiency on profitability (Trinks et al., 2020; Rahmawati & Hartoko, 2024; Oestreich & Tsiakas, 2024). This discrepancy can be explained by differences in research context. Those studies examine cross-country or cross-sector samples, most of which operate under established carbon pricing systems, whereas the present study focuses on a single sub-industry in a jurisdiction where carbon pricing had not yet been implemented. Therefore, rather than contradicting previous findings, this study suggests that the existence of an effective carbon pricing mechanism is a necessary condition for the relationship between carbon management and profitability to emerge.

b. Moderation of the Energy Mix on the CMA–Profitability Relationship

All interaction variables in the profitability models are statistically insignificant, with probability values of 0.3168 for coal, 0.2483 for diesel, and 0.3635 for biodiesel. The interaction coefficient for coal is negative (−0.10936), and the interaction coefficient for biodiesel is also negative (−0.10577), indicating a tendency to weaken the relationship between CMA and profitability. In contrast, the interaction coefficient for diesel is positive (0.20241), suggesting a tendency to strengthen the relationship. However, because none

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of these interaction effects is statistically significant, these directional tendencies cannot be confirmed statistically and should be interpreted only as descriptive patterns rather than inferential findings. Therefore, Hypotheses H3a, H3b, and H3c are rejected. This clarification regarding the limits of interpretation is important because an insignificant coefficient in a small sample may result from limited statistical power rather than the absence of a true effect. With only 30 observations, three predictors in each model, and company fixed effects, the remaining degrees of freedom are limited. Consequently, a moderate effect size could remain undetected. Therefore, the appropriate interpretation is that this study does not provide sufficient evidence to conclude that a moderating effect exists, rather than proving that such an effect does not exist. From a substantive perspective, the absence of a significant moderating effect along the profitability pathway is consistent with the explanation presented in the previous section. If the direct relationship between CMA and profitability has not yet emerged because of the absence of an effective carbon pricing mechanism, then the variable expected to moderate that relationship logically has no relationship to moderate. The finding for biodiesel warrants particular attention. The use of renewable energy has not yet generated a direct improvement in profitability among the observed companies, which may be attributable to the relatively high costs of implementation and energy transition, as well as the price differential between biodiesel and conventional diesel. As a result, the economic benefits of adopting biodiesel had not yet fully materialized during the study period.

c. The Effect of CMA on Carbon Tax Intensity

Unlike the profitability pathway, CMA has a significant effect on carbon tax intensity in two of the three estimated models. The CTI–DSL and CTI–BIO models produce probability values of 0.0026 and 0.0020, respectively, with positive coefficients of 0.00138 and 0.00348. In contrast, the CTI–COL model produces a probability value of 0.1114 with a negative but statistically insignificant coefficient of −0.00034. Because the proposed relationship is supported only in some of the estimated models, Hypothesis H2 is partially accepted. An explicit interpretation of the coefficient magnitude is necessary. In the CTI–BIO model, the coefficient of 0.00348 indicates that a one-unit increase in the natural logarithm of total emissions, equivalent to an increase in emissions of approximately 172%, is associated with an increase in carbon tax intensity of 0.00348, or 0.348 percentage points of total revenue. Given that the average carbon tax intensity is only 0.00207, this effect is economically meaningful because it is equivalent to more than 1.5 times the sample average. In other words, although the carbon tax rate of Rp30,000 per ton of CO_2e is relatively low by international standards, changes in emissions substantially increase fiscal exposure for companies with certain revenue structures. One of the most notable findings is the significant negative coefficient of the coal moderator variable on carbon tax intensity (−0.07185; $p = 0.0031$). This result contradicts the initial expectation that coal, as the most carbon-intensive energy source, would directly increase the carbon tax burden. The explanation for this apparent anomaly lies in the denominator of the dependent variable. Carbon tax intensity is measured as a ratio of carbon tax to total revenue. Consequently, companies with large business scales and high operational efficiency may incur relatively high absolute carbon tax liabilities while still reporting low carbon tax intensity. Companies that rely heavily on coal as an operational fuel generally have larger production volumes and higher revenues, allowing the denominator effect to outweigh the increase in the numerator. This finding highlights the importance of distinguishing between the absolute carbon tax burden and the relative carbon tax burden when designing carbon fiscal policies.

In contrast, the biodiesel ratio has a significant positive direct effect on carbon tax intensity (0.04269; $p = 0.0069$), whereas the diesel ratio has no significant effect ($p = 0.7182$). At first glance, the positive effect of biodiesel appears counterintuitive because biodiesel is generally regarded as a cleaner energy source. However, two mechanisms may explain this result. First, the relatively high costs associated with the energy transition reduce companies' profit margins and net revenue, thereby reducing the denominator of the carbon tax intensity ratio and increasing its value. Second, companies with relatively high biodiesel utilization in this sample generally operate at a smaller revenue scale than companies that primarily use coal. Consequently, although their absolute emissions are lower, their relative fiscal exposure is greater. These findings suggest that transition costs remain substantial, thereby increasing carbon tax intensity relative to

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total revenue. The findings from this pathway support and extend previous studies showing that the management and reporting of emissions data provide the basis for estimating the carbon tax burden borne by firms (Pratama et al., 2022). The contribution of this study lies in its level of analysis. While Pratama et al. (2022) estimate potential carbon tax revenue at the aggregate sectoral level, the present study demonstrates that, at the firm level, the carbon tax burden is distributed disproportionately relative to emissions. These findings also provide firm-level empirical evidence supporting the macro-level conclusion that carbon tax design has important implications for sectoral welfare and competitiveness (Andrianus et al., 2024; Sapiri, 2025). Furthermore, this study complements the findings of Firmansyah and Irawan (2025), who argue that the integration of carbon taxation and sustainability reporting remains suboptimal, by demonstrating that, despite variations in reporting quality, the available emissions data are already sufficient to systematically estimate firms' fiscal exposure.

d. Moderation of the Energy Mix on the CMA–Carbon Tax Intensity Relationship

All interaction variables in the carbon tax intensity models are statistically significant, with probability values of 0.0028 for coal, 0.0186 for diesel, and 0.0059 for biodiesel. Therefore, Hypotheses H4a, H4b, and H4c are accepted. It should be emphasized that this statistical significance refers to the interaction terms rather than the main independent variable. This distinction is essential to avoid misinterpretation in moderation analysis. The interaction coefficient for coal is positive (0.00567), indicating that the coal-use ratio strengthens the relationship between carbon emissions and carbon tax intensity. For companies with a high proportion of coal use, each increase in emissions is associated with a greater increase in the relative carbon tax burden than for companies using other energy sources. This finding is consistent with coal having the highest emission factor among the three fuel types and suggests that the implementation of CMA becomes increasingly important for companies with a high dependence on coal. It is also important to note that this positive moderating effect coexists with the negative direct effect of the coal moderator. Together, these results indicate that coal-intensive companies begin with a lower level of relative carbon tax intensity but experience a steeper increase in carbon tax intensity as their emissions rise. In contrast, the interaction coefficients for diesel (−0.00216) and biodiesel (−0.00348) are negative, indicating that both weaken the relationship between carbon emissions and carbon tax intensity. In companies that use diesel or biodiesel, increases in emissions are associated with smaller increases in the relative carbon tax burden than those observed in coal-intensive companies. This result can be explained by the lower emission factor of diesel relative to coal and, to an even greater extent, by biodiesel, whose biogenic fraction is excluded from Scope 1 emissions calculations under the GHG Protocol.

The moderating effect of biodiesel is supported by stronger statistical evidence than that of diesel, as indicated by its lower probability value (0.0059 versus 0.0186) and its larger coefficient in absolute value. These findings suggest that transitioning from coal to biodiesel reduces the sensitivity of carbon tax exposure to increasing emissions. However, as discussed in the previous section, biodiesel simultaneously has a positive direct effect on the level of carbon tax intensity. Taken together, these findings reveal an implication that would not be apparent if each result were considered separately. Biodiesel reduces the sensitivity of the carbon tax burden to changes in emissions while simultaneously increasing the relative level of the carbon tax burden. From a managerial perspective, this suggests that an energy transition can provide protection against the risks associated with future increases in carbon tax rates or production levels, although it may require firms to accept lower profit margins during the transition period. The high Adjusted R^2 values across all models in this group (0.91318, 0.82328, and 0.85649), together with the significant F-test results for all models ($p = 0.0000$), indicate that carbon emissions, the energy mix, and their interaction jointly explain a substantial proportion of the variation in carbon tax intensity.

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4.7. Synthesis of Findings

A summary of the hypothesis testing results is presented in Table 10. All hypotheses related to the profitability pathway are rejected, whereas all moderation hypotheses related to the carbon tax intensity pathway are accepted.

Table 10. Summary of Hypothesis Testing Results

Hypothesis	Hypothesis Statement	Coefficient	Prob.	Conclusion
H1	CMA has a significant negative effect on profitability	−0,01510; −0,00813; 0,02113;	0,8133; 0,3268; 0,4930	Rejected
H2	CMA has a significant positive effect on carbon tax intensity	−0,00034; 0,00138; 0,00348	0,1114; 0,0026; 0,0020	Partially accepted
H3a	The coal ratio moderates the relationship between CMA and profitability	−0,10936	0,3168	Rejected
H3b	The diesel ratio moderates the relationship between CMA and profitability	0,20241	0,2483	Rejected
H3c	The biodiesel ratio moderates the relationship between CMA and profitability	−0,10577	0,3635	Rejected
H4a	The coal ratio moderates the relationship between CMA and carbon tax intensity (strengthens)	0,00567	0,0028	Accepted
H4b	The diesel ratio moderates the relationship between CMA and carbon tax intensity (weakens)	−0,00216	0,0186	Accepted
H4c	The biodiesel ratio moderates the relationship between CMA and carbon tax intensity (weakens)	−0,00348	0,0059	Accepted

Source: Processed by the author (2026).

This two-path pattern represents the primary contribution of the present study. In the current Indonesian context, carbon management accounting operates through a measurable and deterministic fiscal channel rather than through a market channel driven by investor perceptions. From a theoretical perspective, these findings suggest that coercive pressure within the framework of institutional theory provides stronger explanatory power than market-based legitimacy mechanisms at the current stage of Indonesia's climate policy development. As long as an effective carbon pricing system has not been fully implemented, the benefits of carbon management are unlikely to be reflected in capital market performance. However, the associated fiscal risk exposure can already be measured systematically and with a high degree of precision.

V. Conclusion

This study examines the effect of Carbon Management Accounting (CMA) on profitability and carbon tax intensity, with the energy mix serving as a moderating variable, using a sample of six coal mining companies listed on the Indonesia Stock Exchange during the 2020–2024 period. The findings indicate that CMA has no significant effect on profitability, either directly or when moderated by the energy mix. In contrast, CMA has a partially significant effect on carbon tax intensity, and all three energy mix ratios significantly moderate this relationship. Specifically, the coal ratio strengthens the relationship between CMA and carbon tax intensity, whereas the diesel and biodiesel ratios weaken it. Two findings deserve particular attention. First,

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a higher proportion of coal use is associated with lower carbon tax intensity because the larger revenue base of coal-intensive firms reduces the relative tax burden. Second, although biodiesel is considered a cleaner energy source, its use is associated with higher carbon tax intensity because of the relatively high costs of energy transition, which reduce the revenue base used in the intensity calculation. These findings demonstrate that the relationship between energy choices and carbon tax intensity is influenced not only by emission levels but also by firms' economic characteristics and cost structures. From a theoretical perspective, this study contributes to the literature in several ways. First, the findings suggest that legitimacy theory has limited explanatory power in contexts where an effective carbon pricing mechanism has not yet been implemented. Without a market mechanism that prices carbon performance, improvements in carbon management and emission disclosure are not translated into higher shareholder returns. Second, the findings provide stronger support for institutional theory by demonstrating that coercive institutional pressure, represented by the planned implementation of a carbon tax, already influences corporate behavior through measurable fiscal exposure even before the regulation becomes fully effective. Third, this study extends cost theory by showing that environmental costs should be evaluated from two distinct perspectives, namely their absolute magnitude and their relative intensity, because these dimensions may move in opposite directions, as observed in the case of coal-based energy use.

The findings also offer several practical implications for corporate managers, policymakers, regulators, investors, and creditors. For corporate management, decisions regarding the energy transition should not be justified primarily by expectations of higher short-term profitability, since the empirical evidence does not support such a relationship. Instead, the transition should be viewed as a strategic effort to manage future carbon-related fiscal risks. Companies should also develop activity-based emission inventory systems capable of separating fuel consumption by fuel type and operational unit, enabling more accurate estimation of future carbon tax exposure. Particular attention should be given by firms with relatively small revenue bases, as they are likely to experience a greater relative carbon tax burden during the transition period. For policymakers and regulators, the findings highlight the importance of establishing standardized emission disclosure requirements covering all emission scopes within sustainability reports to improve data consistency and support the implementation of emission-based fiscal policies. Regulatory frameworks should also require companies to disclose verified carbon emission data through independent third-party assurance to improve data reliability. Furthermore, the unequal distribution of the carbon tax burden identified in this study suggests that applying a uniform carbon tax rate may disproportionately affect smaller firms. Therefore, complementary policy mechanisms, such as emission thresholds, temporary transition relief, or targeted revenue recycling, should be considered. In addition, because biodiesel has been shown to significantly reduce the sensitivity of carbon tax exposure to increasing emissions, fiscal incentives supporting biofuel adoption may serve as an effective complement to carbon taxation. For investors and creditors, these findings provide a quantitative basis for incorporating carbon tax exposure into the risk assessment of energy-sector firms by evaluating the composition of the energy mix disclosed in corporate sustainability reports.

Despite these contributions, this study has several limitations. The sample consists of only six publicly listed coal mining companies, resulting in 30 observations and limiting the statistical power of the analysis. Consequently, the insignificant findings related to profitability may partly reflect the relatively small sample size, and the conclusions cannot be generalized beyond publicly listed coal mining companies in Indonesia with adequate sustainability disclosures. In addition, differences in emission measurement methods, reporting scopes, and calculation techniques across companies reduce data comparability, while incomplete disclosure of detailed fuel information required the application of standardized emission factors for Sub-Bituminous Coal and Industrial Diesel Oil across all observations. The study is also subject to methodological limitations, including the absence of mean-centering for interaction variables, indications of positive autocorrelation in two models that were addressed only through robust standard errors, the inability to estimate the Hausman test because of the limited panel dimensions, and the exclusion of potentially relevant control variables such as firm size, leverage, and coal prices. Finally, because Indonesia's carbon tax had not yet been fully implemented during the observation period, carbon tax intensity represents a simulated measure rather than an observed fiscal outcome and therefore cannot fully capture firms' behavioral responses under an operational carbon tax regime. Future research is encouraged to expand the sample by including companies from the broader energy sector or conducting cross-country studies to improve statistical power and enable comparative policy analysis. Subsequent studies should also incorporate additional control variables, such as firm size, leverage, commodity prices, and capital intensity, while considering alternative dependent variables, including profitability after carbon tax simulation, to provide a more comprehensive assessment of the economic effects of Carbon Management Accounting. Future researchers may further improve methodological robustness by applying mean-centering to interaction terms, employing panel-corrected standard errors, or estimating dynamic panel models. Finally, qualitative approaches or in-depth case studies would complement the present quantitative findings by providing a deeper understanding of the managerial considerations underlying corporate energy mix decisions and carbon management strategies.

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