

ENHANCING FINANCIAL PERFORMANCE THROUGH CARBON PRODUCTIVITY, LEVERAGE, AND FIRM SIZE: INSIGHTS FROM AN EMERGING MARKET

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Abstract

The primary purpose of this study is to examine the effects of carbon productivity, leverage, and firm size on the financial performance of manufacturing companies. The data used in this study comprise 277 firm-year observations from 108 manufacturing companies listed on the Indonesia Stock Exchange (IDX) during the period 2022–2024. This study employs panel data regression analysis, and the results of the Hausman test and the Breusch–Pagan test indicate that the Random Effects Model is the most appropriate approach for achieving the study's objectives. The findings reveal that carbon productivity has a positive effect on firms' financial performance in Indonesia, suggesting that companies can gain competitive advantages through more effective carbon emission management strategies. Furthermore, leverage has a negative effect on financial performance, indicating that excessive reliance on debt financing may increase financial burdens and reduce corporate profitability. In addition, firm size is found to have a positive and significant influence on financial performance, implying that larger firms benefit from greater resource availability, economies of scale, and broader access to financing opportunities. Taken together, these findings suggest that improving carbon efficiency and effectively utilizing organizational resources can enhance financial performance, whereas high levels of debt should be carefully managed to mitigate their potential adverse impacts on firm performance.

Keywords: Carbon Productivity, Leverage, Firm Size, Financial Performance, Manufacturing Companies

INTRODUCTION

Financial performance remains a central concern in sustainable business management, as it reflects a company's ability to generate profit while maintaining long-term operational stability and fulfilling financial obligations. In the context of sustainable development, financial performance is not merely an indicator of short-term profitability, but also a signal of a company's resilience and capacity to create long-term value for investors (Venita, 2025). Improved financial performance indicates the achievement of business objectives while also strengthening investor confidence. Companies with strong financial performance tend to be more attractive to investors as they can deliver higher returns on invested capital (Riswan & Martha, 2024; Stefannandra et al., 2022). Financial performance is measured using various financial ratios derived from financial statements, one of which is *Return on Equity* (ROE). ROE measures the effectiveness of a company in utilizing shareholders' equity to generate profit. This ratio reflects the company's ability to deliver returns on capital invested by shareholders, making it one of the key indicators considered by investors in investment decision-making (Setiawan & Pereira, 2021).

The manufacturing sector plays a strategic role in Indonesia's economy as the largest contributor to Gross Domestic Product (GDP), with an average contribution of 18.81% during 2021–2024 (Badan Pusat Statistik, 2025). However, the average ROE of manufacturing companies showed a fluctuating trend, recorded at 6.23% in 2022, rising to 6.87% in 2023, and declining again to 5.48% in 2024. This condition indicates that the companies' ability to generate profit for shareholders remains unstable, raising concerns about their long-term financial sustainability.

The sustainability challenge faced by manufacturing companies extends beyond financial pressures. Manufacturing industry activities are one of the main contributors to carbon emissions (Badan Pusat Statistik, 2025), and growing environmental awareness among regulators, investors, and the public has placed increasing pressure on companies to adopt sustainable business practices. The Indonesian government has imposed strict sanctions on companies that violate environmental regulations, as demonstrated by the Ministry of Environment and Forestry (KLHK) halting the operations of several industrial companies due to air pollution (DetikNews, 2024). This situation underscores the urgency for companies to integrate environmental responsibility into their operational strategies, as failure to do so may jeopardize both regulatory compliance and long-term financial performance.

Carbon productivity, defined as the economic output generated per unit of carbon emission, has emerged as a key indicator that integrates both economic and environmental objectives (Wu & Yao, 2023). A company with high carbon productivity is not only more environmentally efficient but also demonstrates stronger resource management capabilities. From the perspectives of Agency Theory and Resource-Based View (RBV), carbon productivity represents an internal capability that is valuable, rare, difficult to imitate, and non-substitutable, thereby potentially serving as a source of sustainable competitive advantage (Barney, 1991; Jensen & Meckling, 1976).

In addition to carbon productivity, leverage and firm size are recognized as important determinants of financial performance in a sustainability-oriented business environment. Leverage, which reflects the level of debt in a company's capital structure, creates fixed payment obligations that can suppress net profit and limit a company's capacity to invest in sustainable practices. Cases of debt payment suspension (PKPU) among Indonesian manufacturing companies illustrate the financial difficulties arising from high debt burdens (CRIF Asia, 2025). Firm size, proxied by the natural logarithm of total assets, reflects the scale of operations and resource capacity. Larger companies tend to have greater financial stability, broader access to funding, and competitive advantages that may positively influence financial performance and sustainability initiatives (Riswan & Martha, 2024).

Prior studies have produced inconsistent findings on the relationships between these variables and financial performance, particularly in the Indonesian manufacturing context. This study therefore aims to re-examine the effects of carbon productivity, leverage, and firm size on financial performance, measured by ROE, among manufacturing companies listed on the IDX from 2022 to 2024.

LITERATURE REVIEW AND HYPOTHESIS FORMULATION

Agency Theory

Agency Theory, introduced by Jensen and Meckling (1976), defines an agency relationship as a contract in which one or more persons (the principal) engage another person (the agent) to perform services on their behalf, involving a delegation of decision-making authority to the agent. In a corporate context, the principal is typically the shareholder or capital provider, while the agent is the management responsible for running the company and reporting its performance to the principal. The agency relationship can potentially generate conflicts of interest because the principal and the agent have different objectives. This condition is known as the agency problem and can lead to increased agency costs and reduced company performance (Jensen & Meckling, 1976). Information asymmetry, where agents possess more comprehensive information about the

company's condition and operational activities, exacerbates this problem. In the context of this research, carbon productivity reflects the agent's (management's) ability to efficiently manage carbon emissions as part of operational cost control, thereby aligning the interests of agents and principals toward improved financial performance.

Resource-Based View (RBV) Theory

The Resource-Based View (RBV), introduced by Wernerfelt (1984) and further developed by Barney (1991), posits that a company's resources and capabilities are the primary sources of competitive advantage and profitability. A sustainable competitive advantage is achieved when resources are Valuable, Rare, Imperfectly Imitable, and Non-substitutable (VRIN). Carbon productivity can be regarded as an internal capability built through organizational learning, long-term investment in clean technology, and operational experience, making it valuable, relatively rare, and difficult to imitate. Similarly, firm size reflects the breadth of resources (physical assets, financial capital, managerial capabilities) that can be leveraged for operational efficiency and competitive advantage.

Financial Performance

Financial performance reflects the achievement of management in carrying out its governance functions effectively and efficiently within a specific period (Rudianto, 2013). In this study, financial performance is measured using *Return on Equity* (ROE), which measures the effectiveness of a company in utilizing shareholders' equity to generate net profit. ROE is widely regarded as a key metric for investors in evaluating investment decisions (Setiawati & Susanti, 2025)

$$ROE = \frac{Net\ Income}{Total\ Equity}$$

Carbon Productivity

Carbon productivity refers to the economic output generated per unit of carbon emission in a given period. The concept was first introduced by Kaya and Yokobori (1999), originally at the macroeconomic level, and subsequently adopted at the firm level as a measure of environmental and economic performance (Bagchi et al., 2022; Guo et al., 2021). A higher level of carbon productivity indicates that a company is more efficient in generating economic output with lower carbon emissions. In this study, carbon productivity is measured as the ratio of a company's Sales (as a proxy for economic output) to its total carbon emissions (Scope 1 and 2).

$$CP = \frac{Net\ Sales}{Total\ Emissions\ Scope\ 1 + Scope\ 2}$$

Leverage

Leverage refers to the use of assets or funding sources that entail fixed cost obligations in the form of interest on loans (Sutrisno, 2009). In this study, leverage is proxied by the *Debt-to-Asset Ratio* (DAR), calculated as total liabilities divided by total assets. A high DAR indicates a greater proportion of assets financed by debt, which increases financial risk. Under Agency Theory, debt creates a contractual relationship between shareholders, management, and creditors that can give rise to conflicts of interest and increase agency costs (Jensen & Meckling, 1976).

$$DAR = \frac{Total\ Liabilities}{Total\ Assets}$$

Firm Size

Firm size is a measure used to categorize the scale of a company based on its total assets (Riswan & Martha, 2024). In this study, firm size is proxied by the natural logarithm of total assets. Larger companies generally possess greater operational capacity, broader access to funding, and economies of scale that can create competitive advantages. From an RBV perspective, larger firms tend to have more diverse and extensive resources, including physical assets, financial capital, technology, and managerial capabilities, enabling them to operate more efficiently and competitively.

$$Size = \ln (Total\ Assets)$$

Hypothesis Development

Effect of Carbon Productivity on Financial Performance

From an Agency Theory perspective, high carbon productivity reflects the agent's (management's) effectiveness in managing operational resources, particularly in controlling carbon emissions as a component of production costs. A company with high carbon productivity demonstrates the ability to generate greater economic output per unit of carbon emission, indicating efficient resource use that suppresses waste and reduces production costs. This efficiency translates into improved profitability and, consequently, better financial performance. From an RBV perspective, carbon productivity represents a strategic capability that is difficult to imitate, built through technological investment, organizational learning, and long-term sustainability practices, thereby creating sustainable competitive advantage (Barney, 1991). Empirically, Febriani and Darmawati (2025), Ghose et al. (2023), and Makan and Kabra (2021) found a positive relationship between carbon productivity and financial performance. Based on this reasoning, the following hypothesis is formulated:

H1: Carbon productivity has a positive effect on financial performance.

Effect of Leverage on Financial Performance

Under Agency Theory, debt creates contractual relationships among shareholders, management, and creditors, potentially generating conflicts of interest and increasing agency costs. In capital-intensive manufacturing companies, high leverage intensifies financial pressure due to elevated fixed obligations and reduced funding flexibility. The high interest burden can erode net profit, thereby negatively affecting financial performance. Several empirical studies have confirmed this negative relationship (Agung et al., 2024; Gemilang & Wiyono, 2022; Ningsih & Wuryani, 2021), supporting the following hypothesis:

H2: Leverage has a negative effect on financial performance.

Effect of Firm Size on Financial Performance

From an RBV perspective, larger companies tend to possess more extensive and diverse resources, including physical assets, financial capital, technology, and strong managerial capabilities, that enable more efficient operations, optimized use of business opportunities, and sustainable competitive advantage. Larger companies also tend to have better access to external financing, lower financial risk, and greater economies of scale. Empirically, Injayanti et al. (2023), Riswan and Martha (2024), and Setiawan and Pereira (2021) found a positive relationship between firm size and financial performance, supporting the following hypothesis:

H3: Firm size has a positive effect on financial performance.

RESEARCH METHODS

This study employs a quantitative approach using secondary data. The population consists of manufacturing sector companies listed on the Indonesia Stock Exchange (IDX). Data were collected from company annual reports and sustainability/ESG reports for the period 2022–2024. Purposive sampling was applied to select companies that disclosed complete carbon emission data (Scope 1 and Scope 2), were consistently listed on the IDX throughout the observation period, did not experience delisting, and had complete financial data. After removing outliers, the final sample consists of 277 firm-year observations from 108 manufacturing companies across three years.

The dependent variable is financial performance, measured by ROE (Net Income / Total Equity). The independent variables are: (1) *Carbon Productivity* (X1), measured as natural logarithm of total net sales divided by total carbon emissions (Scope 1 + Scope 2, in TonCO2e); (2) *Leverage* (X2), measured by DAR (Total Liabilities / Total Assets); and (3) *Firm Size* (X3), measured by the natural logarithm of total assets.

The regression model used in this study is:

$$ROE = \alpha + \beta_1 CP + \beta_2 LEV + \beta_3 SIZE + \varepsilon$$

Where ROE = Return on Equity; CP = Carbon Productivity; LEV = Leverage (DAR); SIZE = Natural logarithm of total assets; α = Constant; $\beta_1, \beta_2, \beta_3$ = Regression coefficients; ε = Error term.

The data analysis technique uses panel data regression. The best model was selected from the Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM) through the Chow Test, Hausman Test, and Lagrange Multiplier (LM) Test. Prior to hypothesis testing, classical assumption tests, including normality, multicollinearity, and heteroscedasticity tests, were conducted to ensure the validity of the regression results. Hypothesis testing was performed at a significance level of 5% ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Descriptive Statistics

Descriptive statistics for all research variables based on 277 firm-year observations are presented in Table 1 below.

Table 1. Descriptive Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
ROE (Y)	0.0810	0.1015	-0.3213	0.3357
Carbon Productivity (X1)	17.7749	1.8558	12.4313	23.7396
Leverage (X2)	0.3964	0.1982	0.0628	1.3527
Firm Size (X3)	28.8559	1.5846	25.5033	32.9379

Source: Processed data with Eviews13 (2026)

The mean ROE of 0.0810 (8.10%) indicates that, on average, sample companies generated moderate returns on equity over the 2022–2024 period. The standard deviation of 0.1015 reflects considerable variation in financial performance across firms. Carbon productivity (X1) has a mean of 17.77 with a standard deviation of 1.86, suggesting differences in firms' ability to generate economic output per unit of carbon emission. The mean leverage (X2) of 0.3964 indicates that, on average, approximately 39.64% of company assets are financed by debt. Firm size (X3) ranges from 25.50 to 32.94 (natural logarithm of total assets), reflecting the diversity in company scale within the sample.

Panel Data Model Selection

Model selection was conducted through three sequential tests. First, the Chow Test was performed to choose between CEM and FEM. The result yielded a Cross-section F statistic of 4.284 ($p = 0.0000 < 0.05$), indicating that FEM is preferred over CEM. Second, the Hausman Test was conducted to choose between FEM and REM. The Chi-Square statistic was 4.253 with 3 degrees of freedom ($p = 0.2354 > 0.05$), indicating that the null hypothesis cannot be rejected and REM is more appropriate than FEM. Third, the Lagrange Multiplier (LM) Test confirmed the preference for REM over CEM, with a Breusch-Pagan statistic of 68.215 ($p = 0.0000 < 0.05$). Based on these three tests, the **Random Effect Model (REM)** was selected as the most appropriate model for this study.

Classical Assumption Tests

Three classical assumption tests were conducted on the REM residuals. The normality test using the Jarque-Bera statistic yielded a value of 1.202 with a probability of 0.548 (> 0.05), indicating that the residuals are normally distributed. The multicollinearity test using Variance Inflation Factor (VIF) showed values of 1.020 (X1), 1.041 (X2), and 1.060 (X3), all well below the threshold of 10, confirming the absence of multicollinearity among the independent variables. For heteroscedasticity, the residual graph showed that residuals were spread randomly around zero without a systematic pattern, indicating no serious heteroscedasticity in the model. These results confirm that the data meet the classical assumptions required for valid inference.

Hypothesis Testing Results

The REM regression results are presented in Table 2 below.

Table 2. Random Effect Model Regression Result

Variable	Coefficient	Standard Error	t-Statistic	Prob.
Constant (C)	-0.5329	0.1525	-3.4947	0.0006
Carbon Productivity (X1)	0.0147	0.0037	4.0065	0.0001
Leverage (X2)	-0.2714	0.0330	-8.2227	0.0000
Firm Size (X3)	0.0158	0.0045	3.4921	0.0006
R-Squared	0.2370		F-Statistic	28.273
Adjusted R-Squared	0.2287		Prob (F-Statistic)	0.0000

Source: Processed data with Eviews13 (2026)

The F-statistic of 28.273 ($p = 0.0000$) confirms that the model is statistically significant as a whole. The adjusted R-squared of 0.229 indicates that approximately 22,9% of the variation in financial performance (ROE) can be explained by the three independent variables.

Effect of Carbon Productivity on Financial Performance (H1)

The regression results show that carbon productivity (X1) has a positive and significant effect on financial performance (ROE), with a coefficient of 0.0147 and a probability value of 0.0001 (< 0.05). Accordingly, H1 is supported. This finding indicates that companies with higher carbon productivity, meaning they generate greater economic output per unit of carbon emission, tend to report better financial performance. This result is consistent with Agency Theory, in which high carbon productivity reflects the agent's (management's) effectiveness in managing operational resources efficiently: reducing energy waste, controlling production costs, and aligning managerial actions with shareholder interests. From an RBV perspective, carbon productivity represents a strategic internal capability that is difficult to imitate, built through accumulated organizational learning, investment in clean technology, and sustainability-oriented practices, thereby generating competitive advantage that translates into superior financial performance (Barney, 1991).

This finding is aligned with the results of Febriani and Darmawati (2025), who found a positive relationship between carbon productivity and financial performance among energy sector companies in Indonesia, as well as Ghose et al. (2023) and Makan and Kabra (2021) in the Indian market context. It contrasts with Geldres-Weiss et al. (2025), who found a negative relationship in the global meat export industry, possibly due to the high upfront investment required for emission reduction in that sector. It also differs from Tehananda et al. (2025), who found no significant relationship in companies listed on the IDX80 index, potentially reflecting the broader and more heterogeneous nature of that sample compared to the manufacturing sector specifically examined here.

Effect of Leverage on Financial Performance (H2)

The regression results show that leverage (X2) has a negative and significant effect on financial performance (ROE), with a coefficient of -0.2714 and a probability value of 0.0000 (< 0.05). Accordingly, H2 is supported. This finding indicates that higher debt proportions are associated with lower financial performance, consistent with Agency Theory. High leverage creates substantial and fixed debt and interest payment obligations regardless of operating performance fluctuations, which can erode net profit. In capital-intensive manufacturing companies that require large investments, a high debt-to-asset ratio intensifies financial pressure, reduces funding flexibility, and may undermine the firm's ability to invest in value-creating activities.

This finding is in line with the results of Agung et al. (2024), Gemilang and Wiyono (2022), and Refalina et al. (2024), all of whom found a negative relationship between leverage and financial performance. It contrasts with Noegroho and Susilowati (2024), and Qilmi (2021), who found a positive effect, possibly because in those studies, debt was effectively channelled into productive investment. It also differs from Shafirah and Suwandi (2024), and Sinaga et al. (2024), who found no significant relationship.

Effect of Firm Size on Financial Performance (H3)

The regression results show that firm size (X3) has a positive and significant effect on financial performance (ROE), with a coefficient of 0.0158 and a probability value of 0.0006 (< 0.05).

Accordingly, H3 is supported. This finding indicates that larger companies, with greater total assets, tend to generate higher financial performance. Consistent with RBV Theory, larger firms possess more extensive and diverse resources, including physical assets, financial capital, advanced technology, and stronger managerial capabilities. These resources enable companies to achieve economies of scale, reduce per-unit costs, and operate more competitively. Furthermore, larger companies tend to have better access to external financing at lower costs, allowing them to fund profitable investment opportunities more readily.

This result is consistent with the findings of Injayanti et al. (2023), Riswan and Martha (2024) and Setiawan and Pereira (2021), all of whom found a positive effect of firm size on financial performance. It contrasts with Andika and Istanti (2024), and Risna et al. (2021), who found a negative relationship, possibly because larger asset bases in those samples were accompanied by disproportionately high maintenance costs relative to profit generation. It also differs from Jessica and Triyani (2022), and Sari and Setyaningsih (2023), whose findings of no significant relationship.

CONCLUSION

This study examines the effects of carbon productivity, leverage, and firm size on the financial performance (ROE) of manufacturing companies listed on the Indonesia Stock Exchange (IDX) during the period 2022–2024. Based on panel data regression analysis using the Random Effect Model (REM) with 277 firm-year observations from 108 companies, the following conclusions are drawn. First, carbon productivity has a positive and significant effect on financial performance, meaning that companies capable of generating greater economic output per unit of carbon emission tend to achieve higher ROE. Second, leverage has a negative and significant effect on financial performance, indicating that higher debt ratios increase financial burden and suppress profitability. Third, firm size has a positive and significant effect on financial performance, reflecting that larger companies benefit from greater resources, economies of scale, and better access to funding.

These findings contribute to the accounting and finance literature by providing empirical evidence that carbon productivity, as an integrated measure of environmental and economic efficiency, is a meaningful predictor of firm financial performance in the Indonesian manufacturing context, supporting both Agency Theory and Resource-Based View (RBV). Practically, the results suggest that company management should prioritize strategies to improve carbon efficiency (e.g., investment in clean technology, process innovation, energy efficiency), maintain an optimal capital structure to avoid excessive financial burden, and leverage company size advantages to enhance operational efficiency and competitive positioning.

This study has several limitations. The carbon emission data relied on voluntary disclosure in annual and sustainability reports, which may not be available for all manufacturing companies, thereby limiting the sample. The observation period is restricted to three years (2022–2024), which may not fully capture long-term dynamics. Future research is encouraged to extend the observation period, incorporate additional variables such as environmental performance scores (PROPER), corporate governance mechanisms, or CSR expenditure, and explore potential moderating or mediating relationships in this context.

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