Corporate Performance under Carbon Pressure: The Role of CO2 Emissions and Management in Asean Firms

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Abstract

Climate change and environmental pollution have become serious issues that need to be addressed. In this context, this study analyses the impact of CO_2 emissions management on the financial performance of enterprises in four Southeast Asian countries, namely Vietnam, Cambodia, the Philippines and Singapore. Using an OLS regression model, the study focuses on two environmental indicators: actual CO_2 emissions and CO_2 emissions management strategies such as emissions control, energy efficiency improvement and green innovation. The result show that CO_2 emissions and financial performance have an positively corelated: enterprises with high emissions tend to have lower profits. In contrast, enterprises that adopt effective emissions management measures such as emissions reduction and energy saving tend to achieve better financial results, especially in countries with strict environmental policies. This study contributes to both the academic literature on emissions management and provides specific evidence for the Southeast Asia region – which is lacking in global climate finance studies. At the same time, the study provides recommendations for managers and government agencies in promoting sustainable development linked to financial performance.

Research purpose:
The purpose of this study is to assess the impact of CO_2 emissions and emissions management measures on the financial performance of enterprises in four ASEAN countries (Vietnam, Cambodia, Philippines and Singapore), to determine whether environmental policy compliance creates risks or competitive advantages for enterprises.

Research motivation:
The study is motivated from the urgent need to address climate change and the lack of empirical evidence on the relationship between CO_2 emissions management and corporate financial performance in the context of ASEAN countries strengthening environmental policies.

Research design, approach, and method:
The study uses a quantitative approach with OLS regression models, based on survey data in four ASEAN countries. The main variables include CO_2 emissions index (Scope 2), emissions management index, and financial performance which is return on sales (ROS), along with control variables such as size, age, labor productivity, and industry.

Main findings:
The results illustrates that CO_2 emissions are positively associated with ROS, implying short-term gains from emission growth linked to business expansion. In contrast, proactive carbon management (CM) improves both ROS and ROE, highlighting the benefits of energy efficiency and sustainability practices. Labor efficiency (LE) enhances profitability, while labour growth (LG) reduces it without productivity improvements. Firm size has mixed effects—negative for ROS in pooled models, positive with fixed effects, but consistently lowers ROE due to capital intensity. Overall, the findings emphasize that while emissions may yield temporary gains, long-term value comes from carbon management and operational efficiency.

Practical/managerial implications:

The results of the study provide practical evidence for managers and policymakers that investing in CO_2 emissions management not only helps to comply with environmental regulations but also improves financial performance. Enterprises should integrate sustainable development strategies into their core operations to enhance competitiveness, while governments should promote supporting mechanisms such as carbon taxes and green incentives.

Keywords: carbon emissions, financial performance, carbon management, ASEAN, energy.

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1. INTRODUCTION

The international community acknowledges the critical necessity of mitigating climate change has propelled the reduction of greenhouse gas (GHG) emissions, particularly carbon dioxide (CO2), to the forefront of international policy agendas [1]. As the primary anthropogenic driver of climate change, CO2 emissions from industrial activities have become a central target for regulatory interventions aimed at mitigating environmental degradation and fostering sustainable development. This global imperative has triggered a wave of emission policies and regulations worldwide, profoundly impacting the strategic and operational landscapes of businesses across diverse sectors. Companies are now faced with the dual challenge of navigating increasingly stringent environmental requirements while simultaneously maintaining or enhancing their competitive position and financial performance. Integrating effective CO2 emission management into core business strategies is no longer a matter of corporate social responsibility but a critical factor for long-term survival and success [2].

Climate Change and the Imperative of Emission Policies: The scientific evidence linking GHG emissions to climate change is overwhelming, underscoring the urgent need for substantial and immediate reductions in CO2 emissions [1]. The Paris Agreement, a landmark international accord, has set ambitious goals for limiting global warming, requiring signatory nations to implement policies and measures to reduce their carbon footprints. Assessing the Impact of Emission Management on Corporate Financial Performance and Operations: To quantitatively analyze the relationship between various CO2 emission management practices and corporate financial and operational performance indicators. This will involve examining the impact of specific strategies such as investments in renewable energy sources, adoption of energy-efficient technologies, implementation of carbon capture and storage systems, participation in carbon trading schemes, and adoption of circular economy principles. Financial performance will be assessed using metrics such as profitability (e.g., net profit margin, return on equity), revenue growth, cash flow, and market capitalization. Operational efficiency will be evaluated using metrics such as productivity, energy intensity, material consumption, and waste generation.

Overall, while emission policies may create initial financial pressure, if implemented correctly, they can serve as a catalyst for innovation and sustainable growth. Businesses should not view these regulations solely as barriers but rather as opportunities to improve operational efficiency, enhance brand value, and establish a strong market position in the long run. The study used regression to analyses the impact of emissions indicators on financial performance of enterprises in four Southeast Asian countries: Vietnam, Cambodia, Philippines and Singapore.

This study specifically aims to answer the following questions:

Q1: How do emission policies impact corporate profitability?

Q2: Do businesses suffer negative effects from emission regulations?

Q3: Does policy compliance create a competitive advantage or pose risks for businesses?

The rest of study is organized as follows. In Section 2, we conducted a systematic literature review on related research and methods to measure impact of CO2 emission management on firm performance. Section 3 provides the study design to evaluate such impact including description of dataset and theoretical framework. Section 4 shows and interpret the estimated results. The latest section briefly concludes the study.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1 Thematic analysis of correlation between CO_2 monitor and CO_2 management on firm performance

In the context of increasing global challenges posed by climate change, CO_2 monitoring and management have become critical components of corporate sustainability strategies. Beyond mere regulatory compliance, these carbon management solutions are proving to significantly enhance various aspects of non-financial performance. The main research themes could be classified as follows:

2.1.1 Proactive CO_2 Monitoring and Management Enhance Both Financial and Non-Financial Performance

Multiple studies (e.g., Hart et al., 2006; Eccles et al., 2012; Brooks & Oikonomou, 2018) show that voluntary and strategic carbon management, beyond regulatory compliance, can improve corporate reputation, innovation, stakeholder relationships, and even financial returns such as ROA. Firms that proactively reduce emissions often experience better market valuation, investor confidence, and long-term sustainability benefits. The research by Hart et al (Hart et al., 2006) concludes that proactive environmental strategies, particularly emissions reductions, are positively associated with improved firm financial performance. Firms that voluntarily adopt pollution prevention measures tend to experience economic benefits, whereas those that reduce emissions only to comply with regulations do not see the same positive outcomes—in some cases, they may even suffer financial setbacks. Furthermore, the other research by Eccles (Eccles et al., 2012) proves that robust CO_2 management significantly enhances non-financial performance by improving corporate reputation, strengthening brand image among environmentally conscious consumers, attracting and retaining talent, fostering innovation, and enhancing relationships with stakeholders, such as investors who increasingly factor environmental and governance (ESG) criteria into their decisions. The conclusions of the research by Hart and Eccles highlight the importance of proactive environmental strategies for firms. Both studies underline the importance of adopting proactive and robust environmental strategies to improve the firm's performance. The research by Brook (Brooks & Oikonomou, 2018) concludes that the monitoring and management of CO_2 emissions have positive impact on financial and non-financial performance of firms. The study highlights that companies engaging in transparent and proactive carbon management, especially through detailed and credible disclosure of emissions data and strategies, are generally awarded by investors. Such firms signal strong governance, effective risk management, and alignment with long-term stakeholder interests, all of which contribute to improved market valuation and financial returns.

The differential impact of carbon emissions on financial performance across financial and non-financial sectors is increasingly becoming a central focus of scholarly inquiry. In the study by Ganda & Milondzo (2018), firms were divided into two groups: clean sectors (including financial companies, consumer services, healthcare) and dirty sectors (manufacturing, heavy industry, energy). The results showed that: Financial firms (in the clean sector group) have low emissions and are less affected by direct emissions, but ROI and ROE still decrease when Scope 1 emissions increase. This shows that long-term investors are still interested in sustainability factors. Non-financial firms (especially in high-emission industries) are more negatively affected when carbon emissions increase, with financial performance decreasing in all three indicators: ROE, ROI and ROS. This reflects the higher sensitivity of this industry group to environmental risks and carbon policies.

2.1.2 CO_2 Monitoring Enables Strategic Decision-Making and Long-Term Value Creation

CO_2 monitoring is not just a compliance tool but a strategic enabler for identifying emission sources, improving cost-efficiency, validating storage methods, and guiding informed decarbonization investments. When integrated into corporate governance, it supports long-term sustainability, operational optimization, and competitive advantage. Research highlights that robust CO_2 monitoring is essential for accurate data collection, enabling informed decarbonization strategies, cost savings, and performance optimization (e.g., Preston et al., 2005; Hart et al., 2006). There are research that prove that CO_2 monitoring and management can bring financial benefit. It shows that the financial impact of CO_2 monitoring is primarily indirect and enabling, rather than a direct cost-benefit analysis of the monitoring itself (Preston et al., 2005). In addition, the research demonstrates that robust CO_2 monitoring is indispensable for validating the security and effectiveness of CO_2 storage such as the Enhanced Oil Recovery (EOR) project. Accurate monitoring provides the essential data foundation to move beyond broad estimates, allowing organizations to precisely identify sources of emissions and quantify the potential cost savings achievable through targeted interventions, such as energy efficiency improvements or process optimizations (Hart et al.,2006). Therefore, investing in CO_2 monitoring not only enhances the accuracy of cost-benefit analyses but also brings clear cost benefits. It enables companies to make more informed decisions about decarbonization investments, justifying expenditures by relying on measurable returns, both financial and non-financial. Managing CO_2 as a strategic variable will help optimize performance and deliver long-term benefits for businesses.

Many previous studies have consistently concluded that the monitoring and management of CO_2 emissions have a significant and multi-dimensional positive impact on the financial and non-financial performance of firms. The growing body of academic and empirical research underscores that carbon monitoring and management are not just tools for regulatory compliance, but strategic initiatives that enhance a firm's overall sustainability, operational strength, and market credibility. The research show the impact of the European emission trading scheme (EU ETS) on multiple measures of economic performance (Marin et al., 2017) demonstrates that CO_2 monitoring and management have significant implications for firm performance. They conclude that the EU ETS did not have negatively impact on economic factors of participating firms and can even promote strategic productivity and improve the company's financial performance. The other research on European Companies about influence of carbon management on financial performance (Tuesta et al., 2020) shows that companies with better carbon management practices tend to have higher profitability, especially in terms of return on assets (ROA). The findings from this study also underscore a correlation between the implementation of Environmental Management Systems (EMS) and superior corporate financial performance. This suggests that firms investing in carbon reduction strategies not only comply with environmental regulations but also gain financial benefits. Research investigating the affection of carbon management on financial performance explored that carbon management significantly impacts the financial performance of European companies, particularly their return on assets (ROA), with varying effects depending on the industry's sensitivity to pollution (Tuesta et al., 2020). The study highlights that effective carbon management, including reducing emissions and improving carbon performance, can enhance financial outcomes, especially when aligned with external ratings and internal controls. These findings underscore the importance of integrating environmental strategies into corporate governance to achieve both ecological and economic benefit.

To summary, the reviewed literature converges on a strengthening consensus that proactive CO_2 monitoring and management function as pivotal strategic drivers for both financial and non-financial corporate performance. A consistent finding across multiple studies is that voluntary, transparent, and integrated carbon management strategies typically yield superior outcomes compared to reactive or compliance-driven approaches. These strategic orientations contribute not only to enhanced regulatory alignment but concurrently bolster brand reputation, stakeholder confidence, and operational efficiencies. However, a research by Preston(Preston et al., 2005) highlights that financial benefits are often indirect, materializing through improved data for decision-making rather than immediate cost reductions. While findings show little contradiction, the literature indicates variations in impact magnitude based on factors like industry-specific emission sensitivity and the presence of environmental management systems. Collectively, the evidence furnishes a compelling rationale for the integration of CO_2 management into broader corporate strategy, positioning it not solely as an environmental necessity but as a route to sustained business value.

2.2 Impact of Co2 emissions on firm performance

The scrutiny surrounding the effect of CO2 emissions on firm performance has intensified, primarily driven by the escalating pressure on corporations to mitigate environmental externalities. As climate concerns intensify, companies are expected to assess and reduce their environmental footprints. Studies have examined not only the financial effects of CO_2 emissions but also their influence on reputation, regulatory compliance, and stakeholder engagement. The research analyse a panel dataset of 104 financial and 328 non-financial firms spanning the period from 2011 to 2020, the research reveals that elevated carbon emissions are significantly associated with a decline in several performance metrics, namely Return on Equity (ROE), Tobin's Q, Z-score, and credit ratings. [5]. The negative effects were more pronounced in non-financial firms, which typically have higher emission levels. These findings highlight the importance of carbon management strategies, especially for non-financial firms, to enhance financial stability and market valuation. The previous study provides empirical evidence that higher CO_2 emissions is associated with diminished financial performance among energy companies in BRICS nations. Specifically, their analysis reveals that increased CO_2 emissions correlate with lower Return on Assets (ROA), Return on Invested Capital (ROIC), and market capitalization, all statistically significant at the 5% level [6] This indicates that firms with higher carbon emissions tend to experience reduced profitability and market valuation. These results highlight the economic advantages of adopting cleaner technologies and reducing carbon emissions, emphasizing the importance for energy companies to invest in sustainable innovations to improve their financial outcomes.

Numerous studies have demonstrated that CO_2 emissions significantly influence corporate financial performance and business development. Implementing emission mitigation strategies has the potential to elevate a firm's standing, attract eco-conscious investors and customers, and increase profitability. Such environmental initiatives may serve as a competitive advantage and contribute to greater financial stability. However, the long-term financial implications of carbon management remain insufficiently explored, necessitating further research to support businesses, policymakers, and investors in aligning environmental responsibility with economic performance.

In the scenario of global climate change, firms in the ASEAN region are increasingly facing pressure from governments, investors, and civil society to reduce greenhouse gas emissions, particularly CO_2 the main factor of greenhouse effect. With the relationship between CO_2 emissions, emission management practices, and corporate performance, this relationship has become a critical area of research. Handoyo et al. (2024) emphasized that in major ASEAN economies such as Indonesia, Malaysia, Thailand, the Philippines, and Singapore, factors like corporate social responsibility (CSR), green innovation, and corporate governance play significant roles in enhancing firms' CO_2 emission reduction performance. Companies that actively invest in environmentally-friendly technologies and embed sustainability into their long-term are inclined to manage emissions efficiently, which in turn enhances operational efficiency and overall financial outcomes

However, the relationship between CO_2 emissions and firms performance is not homogeneous across countries and industries. Zhang and Li found that foreign direct investment (FDI) in countries like Singapore and Indonesia tends to increase CO_2 emissions in the short term due to limited technology transfer. In contrast, Vietnam has shown a negative long-term relationship between FDI and emissions, attributed to better adoption of clean technologies. This emphasizes the significance of institutional frameworks and corporate capacity in moderating the influence of industrial activities on the environment. On the topic of environmental disclosure, a joint report by the Global Reporting Initiative (GRI) and the National University of Singapore (NUS) Business School (2022) revealed that 70% of top-listed ASEAN firms reported climate-related information in 2020/2021. However, the quality and comprehensiveness of these disclosures varied. While companies in the Philippines had the highest rate (80%) of greenhouse gas (GHG) reporting, Vietnam had the lowest (5%). This gap reflects disparities in climate governance maturity and stakeholder pressure across ASEAN nations. There is also growing evidence that proactive CO_2 management can generate competitive advantages. Nguyen and Tran (2024) suggested that transparent carbon disclosure not only enhances firm value but also moderates the influence of firm-specific variables such as size and liquidity on financial outcomes. This finding aligns with legitimacy theory, which posits that firms can gain long-term economic value by aligning their operations with social and environmental expectations.

Policy instruments across ASEAN also play a vital role. Singapore became the first ASEAN country to implement a carbon tax in 2019, with planned increases through 2030. Other countries such as Indonesia, Malaysia, and Thailand are currently undertaking the development of Emission Trading Systems (ETS) as part of their national climate action plans. At a regional level, ASEAN launched the Carbon Neutrality Strategy in 2024, which aims to unlock USD 3.7–6.7 trillion in green investments and generate up to USD 5.3 trillion in additional GDP by 2050 (VNTR, 2024). These ambitious policies are expected to significantly shape corporate behavior and investment flows in the coming decades. Nevertheless, current studies are not without limitations. Much of the literature draws from developed economies and short-term data, lacking regional-specific insights from ASEAN. In addition, industry-level variation (e.g., financial vs. non-financial firms, large vs. SMEs) remains underexplored. This gap presents opportunities for more targeted research using ASEAN-based datasets and a comparative sectoral approach.

2.3 Methods to measuring the impact of emissions management on corporate performance.

In empirical research that investigates the relationship between corporate emissions and financial performance, Ordinary Least Squares (OLS) regression has established itself as a central and indispensable method. The simplicity, interpretability, and flexibility of OLS make it particularly suitable for examining linear associations between environmental indicators and financial indicators including Return on Assets and Return on Equity. A comprehensive review of recent studies demonstrates the robustness and flexibility of OLS in identifying environmental practices. For instance, the research (Busch et al., 2020) revisited and extended the findings of Delmas (Delmas et al., 2015), using OLS regression to assess whether carbon emissions had a consistent effect on firm financial performance across different geographies and time periods. Their study utilized ROA and Tobin’s q as the primary dependent variables and found, somewhat paradoxically, that firms with higher emissions showed better financial outcomes, suggesting that market incentives may still favor pollution-intensive firms absent stringent regulation. Similarly, in their large-scale study, research by Lee (Lee et al., 2015) applied panel data and OLS estimators to evaluate how voluntary climate disclosure and engagement with the Carbon Disclosure Project (CDP) impacted firm performance. The results indicated a favorable relationship between environment transparency practices and financial performance, reinforcing the importance of voluntary reporting in shaping investor perceptions. Research by Islam (Islam, 2022) further explored these dynamics by employing OLS and fixed-effects models to examine how environmental disclosures and corporate social responsibility (CSR) strategies exert an influence on firm profitability in emerging economies. Their findings underscore the utility of OLS in revealing the nuanced role of environmental transparency in shaping financial resilience.

Research about the effect of Carbon Emissions Reduction on Corporate Financial Performance (van Emous et al., 2021) by Emous uses OLS regression to estimate that effect. This study employs an extensive international dataset encompassing 53 countries, with observations spanning the period from 2004 to 2019. The final sample comprises 9265 firm-year observations drawn from 1785 distinct companies. They discovered that lowering carbon emissions boosts the ROA, ROE and ROS but has no influence on the Tobin's Q or the current ratio. Specifically, study utilizes OLS within a panel data framework to analyze how carbon management performance affects ROA(Miah et al., 2021) . This model allows for controlling firm-specific and time-related effects, and it evaluates how ESG indicators and greenhouse gas emissions influence financial outcomes. Meanwhile, some studies took a more integrated approach by using a simultaneous equations model, estimated via Three-Stage Least Squares (3SLS), to jointly analyze how environmental performance (measured by the ratio of recycled toxic waste), environmental disclosure (quantitative disclosure in annual reports), and economic performance (industry-adjusted returns) interact (Al-Tuwaijri et al., 2004). This model acknowledged the potential endogeneity across the three dimensions and provided a more accurate estimation than separate regressions. The results showed that firms with superior environmental performance not only had better financial performance but also provided more extensive environmental disclosures, supporting a strategic alignment across dimensions.It is evident that the Ordinary Least Squares (OLS) regression model has played a fundamental role not only in earlier research but also continues to serve as a critical analytical tool in more recent studies. Its simplicity, interpretability, and ability to estimate relationships between variables with relatively few assumptions have made it a extensively used method in empirical economic and environmental research

Secondly, the DID model is useful in environmental economics, where randomized trials are often infeasible. It estimates the causal impact of policies, such as carbon pricing or emissions regulations, by evaluating temporal differences in outcomes between the treatment group (affected firms) and a control group (unaffected firms). This approach helps control for confounding factors, assuming parallel trends in the absence of intervention. The DID model is effective in evaluating the impact of policies like carbon taxes or emission trading schemes on business performance, accounting for differences in industries, regions, and firm characteristics, ensuring accurate insights into regulatory effects on firms. Research by Zhou et al.(Zhou et al., 2023) utilized a difference-in-differences (DID) model to examine the effect of China’s national Emissions Trading Scheme (ETS) on enterprise resource allocation efficiency. This quasi-experimental approach compares firms subject to the ETS (treatment group) with those not subject to it (control group), both before and after policy implementation. By doing so, the model isolates the causal impact of the ETS from confounding trends. They extend this model by incorporating fixed effects to control the influence of unobserved time-invariant firm attributes and time-specific disturbances while performing robustness analyses comprising placebo tests and propensity score matching (PSM) to address selection bias. As proof, the DID model offers a rigorous framework for studying the impact of CO_2 emissions regulations on businesses. Its ability to control for confounding factors and provide causal insights in non-randomized settings makes it a valuable tool for researchers and policymakers aiming to understand how environmental regulations affect business outcomes, particularly in the context of the global transition toward a low-carbon economy.

Thirdly, panel regression models play a fundamental and increasingly indispensable role in environmental and corporate finance research, especially within research that investigates the influence of carbon emissions on corporate performance. These models are uniquely suited to analyze datasets that span across time and include multiple entities—such as firms, countries, or industries—by combining cross-sectional and time-series data. This multidimensional capacity allows researchers to not only control for unobservable heterogeneity among units but also to track dynamic changes over time, making panel regression ideal for complex environmental-economic relationships. For instance, the research by Lewandowski (Lewandowski, 2017) employed a panel regression model with a non-linear specification to analyze 7625 firm-year observations, revealing a curvilinear association between carbon performance and financial performance is favorable for environmentally leading firms but adverse for firms that lag in environmental standards. The panel data approach enabled differentiation between cross-sectional and time-series effects, offering a nuanced understanding of when and how it pays to be green. Similarly, the study by Makeeva (Makeeva et al., 2024) used panel data from BRICS countries to evaluate the impact of green energy patents on firm performance. The application of panel regression facilitated the analysis of multiple financial indicators like ROA, ROIC, and market capitalization, revealing statistically substantial relationships that varied by patent type and country-specific policies. Overall, panel regression models enable researchers to control for unobserved heterogeneity, isolate the impact of environmental performance across time and sectors, and capture dynamic effects—making them indispensable for exploring the multifaceted links between sustainability practices and financial outcomes.

Empirical studies find out that the relationship between emissions management and financial performance have relied on a range of methodological tools, each offering distinct advantages. Ordinary Least Squares (OLS) regression remains foundational due to its simplicity and effectiveness in identifying linear relationships between environment factors and financial indicators such as ROE, ROA and ROS. Advanced applications, including panel data analysis and fixed effects models, enhance its capacity to account for temporal and firm-level variations. Meanwhile, Difference-in-Differences (DID) models provide a robust quasi-experimental framework to estimate the causal impact of environmental regulations like Emissions Trading Schemes, controlling for confounding variables across time and treatment groups. Panel regression models further strengthen these analyses by integrating both cross-sectional and time-series data, capturing dynamic interactions and unobserved heterogeneity. Together, these methodologies have uncovered critical insights: carbon reduction strategies can positively influence financial outcomes, but these effects often depend on context, regulation, and firm characteristics. As the field advances, future research should focus on refining these models, improving data consistency, and adapting methods to industry-specific and regional dynamics to guide more informed and effective carbon management strategies.

3. Research design

3.1 Sample and data

The raw dataset is confidentially provided by the World Bank enterprise surveys released in 2023, which focus on various factors shaping the business environment. The Enterprise Surveys cover topics businesses encompasses a wide array of factors, including infrastructure, trade, finance, regulatory frameworks (regulations, taxes, business licensing), issues related to governance (corruption, crime, informality), innovation, labour dynamics, and stakeholder perceptions regarding barriers to commerce across 154 countries. For the purposes of this research, four countries and 3,172 enterprises were selected for analysis. The dataset also includes the green economy indicator, which measures CO_2 emission, enabling the authors to analyze carbon emissions, financial performance, and CO_2 management.

The Greenhouse Gas Protocol introduces the concept of scope, which distinguishes between direct and indirect emissions from gases, CO_2, and fossil fuels. According to the Greenhouse Gas Protocol Initiative [13], There are three types of scope are defined. Scope 1 refers to direct emissions from sources owned or controlled by the company; these emissions arise from activities such as fossil fuel combustion, production-related chemical emissions, and emissions from company-owned transportation vehicles. Scope 2 is defined as indirect emissions from the consumption of purchased energy, primarily electricity, which arises when a company purchases energy from external sources instead of generating it themselves. Scope 3 is calculated by indirect emissions from sources other than purchased electricity, such as upstream and downstream activities within the supply chain that are not controlled by the company.

In this research, we focus on Scope 2 emissions to calculate carbon performance, due to availability of the dataset. The sample of this paper consists of 3172 firm observations. This sample covers CO2 management, financial, and CO2 emissions in scope 2 of 3172 firms in 4 different countries in 2023. This sample covers manufacturing and reselling enterprises.

Table 1 illustrate the descriptive statistics firm sample by country. The descriptive statistics shows that Vietnam is the country has the highest number of observations among the four countries, followed by the Philippines in second place with 1002 observations, accounting for 31.6% of the total observations. The remaining two countries, Cambodia and Singapore, have the number of observations of 519 and 623, respectively. With sample by size, there are approximately 1,372 small businesses, accounting for about 43.2% of the total 3,172 businesses. There are around 1,046 medium-sized businesses and 747 large businesses, accounting for 32.9% and 23.5%, respectively. By industry, the manufacturing business holds the largest share with 1,380 observations, accounting for approximately 43.5%. Following closely are retail trade and hotels with about 404 and 403 observations, each accounting for around 12.7%. The least observed is the restaurant industry, with 135 observations, representing 4.2%. The second least is the provide services sector, with 183 observations, accounting for 5.9%. The remaining two industries, wholesale and construction, have 343 and 324 observations, respectively. This illustrates that this dataset focuses on manufacturing industry and retail trade. Moreover, this dataset also focuses on small firm instead.

Table 1. Sampling Firms in dataset

	Number of firms	**% of firms**
By country		
Vietnam	1028	32.4%
Cambodia	519	16,4%
Singapore	623	19.6%
Philippines	1002	31.6%
By firm size		
Small	1372	43.2%
Medium	1046	32.9%
Large	747	23.5%
Unknown	7	0.4%
By industry		
Manufacture	1380	43.5%
Retail trade	404	12.7%
Wholesale trade	343	10.8%
Construction	324	10.2%
Hotel	403	12.7%
Restaurant	135	4.2%
Provide services	183	5.9%
Total	**3172**	**100%**

3.2 Variables and measurement

Table 2 provides an overview of what indicators we used in this research. To clarify, we introduce dependent variables. The study utilizes a regression model to analyze the impact of CO2 monitor and CO2 emissions on firm performance, where corporate performance is the dependent variable. With the independent indicators, there are CO2 emissions and CO2 management. This study uses the OLS equation with finance performance (ROS) as the dependent variable The data with a one-year time lag is transformed. ROS is calculated by taking the revenue of 2022, subtracting all expenses for the year, and dividing by the total revenue of 2022.

We focus on analyzing the scope 2 carbon emissions. In this case, $\mathrm{CP_t}$ represents the CO2 emissions index in year t (in this research is 2022), calculated by dividing the total CO2 emissions in scope 2 by one part of 10^6 of the total revenue for 2022 [5] calculated by equation:

$$\mathrm{CP}_t = \frac{\mathrm{TC}_t}{\text{Total sales in year } t\ /10^6} \qquad (1)$$

Moreover, $\mathrm{TC_t}$ is the total number of CO_2 emissions in year t index is calculated by equation (2):

$$\mathrm{TC}_t = \mathrm{e} * 12 * \mathrm{b}_t \qquad (2)$$

Where, e is the average electricity consumption per month. b_t is the CO2 emission factor according to the national electricity grid in year t.

CP_{t-1} represents the CP_t for year t minus one (in this research is 2021), calculated by equation (3):

$$CP_{t-1} = \frac{TC_{t-1}}{\text{Total sales in year } t-1\ /10^6} \quad (3)$$

TC_{t-1} The total CO2 emissions for year t - 1 are calculated by equation (4):

$$TC_{t-1} = \frac{e}{1+g} \times 12 \times b_{t-1} \quad (4)$$

Where, g is the growth factor based on revenue for 2021 and 2022. Calculated by taking the revenue for 2022, subtracting the revenue for 2021, and dividing by the revenue for 2021; e is the average electricity consumption per month in year t; $b_{t-1}$is the CO_2 emission factor according to the national electricity grid in year t – 1.ΔCP is the improvement in carbon performance in 2021 and 2022, or we could say is the difference between CP_{t-1} and CP_t. CM is an index representing whether the company employs energy management measures. This index is equal to 1 if the company has energy management measures and equal to 0 if the company does not have energy management measures

Size, age, LE, LG, and CU is the control variables in this model. Size represents the firm size, which is calculated by taking the logarithm of the total assets of the firm [6]. Age represents the number of years the company has been in operation. LE is the labor efficiency of the firm, calculated by dividing the total revenue for 2022 by the total annual cost of labour [4]. LG is an index representing the growth potential of the number of employees, defined as the number of employees in 2022 minus the number in 2021, divided by the total number of employees in 2021. Capacity Utilization (CU) is defined as the ratio of an establishment's actual output to its maximum potential output, reflecting the degree to which all available physical capital is being utilized.

The fixed variables in the model include Firm country, Firm size and Firm industry to control for the heterogeneity of firms across countries, sizes and industries. Specifically, the country variable identifies the national context of each firm and is coded as a categorical variable with four levels while the firm size variable classifies enterprises into three levels based on their operational scale and the industry variable reflects the sector in which each firm operates and is represented by a seven-level categorical classification: These variables are included as dummy variables in the empirical analysis to capture structural differences among firms and ensure robustness in estimating the production function and firm performance.

To control the heterogeneity of firm across countries, industries, and its size, we introduce dummy variables for each country (4-level), each industry (7-level), and each firm size (3-level). (Chọn 1 trong 2)

Table 2. Variable definition

Variable	Variable names	Description
Firm performance variable		
ROS	Return on sales	Profit in year t / Total sale in year t
Carbon performance variables		
CP_t	Carbon performance in year t	Total number of Co2 emission in year t / Total sale in year t
CP_{t-1}	Carbon performance in year t - 1	Total number of Co2 emission in year t - 1 / Total sale in year t - 1
ΔCP	Difference of carbon performance	Difference of CP_t and CP_{t-1}
CM	Carbon management	CM = 1 if establishment adopts any energy management measures to reduce emissions, waste, or pollution, = 0 otherwise
Firm control variables		
age	Age of firm	The year that establishment established
size	Size of firm	Measures as the natural logarithm of total asset
LE	Labor efficiency	Total sale / Total annual cost of labor including wages, salaries, bonuses, security payment

LG	Labor growth	Difference of total number of full-time workers in year t and year t – 1 / Total number of full-time workers in year t - 1
CU	Capital utilization	The percentage of the maxim output possible if using all the physical
Fixed factor		
country	Firm country	1 = Vietnam, 2 = Cambodia, 3= Singapore, 4 = Philippines
fsize	Firm size	1= small, 2 = medium, 3 = large
industry	Firm industry	1 = manufacture, 2 = retail trade, 3 = wholesale trade, 4 = construction, 5 = restaurant, 6 = service, 7 = hotel

3.3 Model specification

The model to analyze the carbon management, carbon emissions, and financial performance relationship, which is specified as 5 equations below. This equation includes FP as financial performance, which is the dependent variable calculated based on ROS. The independent variables are ΔCP and CM, which stand for carbon emission and carbon management respectively. These indicators represent the ability to adopt energy waste or carbon waste. ΔCP illustrates the difference between the amount of CO_2 emissions in scope 2 in 2021 and 2022. In addition, the control variables are size, age, LE, CU, and LG. All these indicators show efficiency of using labor, machines, and labor growth. In this equation, it is expected to observe a negative relationship between CP and ROS, meaning that the smaller the ΔCP, the higher the ROS, and a positive relationship between CM and ROS, meaning that companies with a focus on energy management are expected to obtain an increase in their profits.

$$FP_{it} = \beta_0 + \beta_1 CM_{it} + \beta_2 \Delta CP_{it} + \beta_3 age_{it} + \beta_4 size_{it} + \beta_5 LE_{it} + \beta_6 CU_{it} + \beta_7 LG_{it} + \mu_{it} + \varepsilon_{it} \quad (5)$$

$$FP_{it} = \beta_0 + \beta_1 \Delta CP_{it} + \beta_2 age_{it} + \beta_3 size_{it} + \beta_4 LE_{it} + \beta_5 UC_{it} + \beta_6 LG_{it} + \varepsilon_{it} \quad (6)$$

$$FP_{it} = \beta_0 + \beta_1 CM_{it} + \beta_2 age_{it} + \beta_3 size_{it} + \beta_4 LE_{it} + \beta_5 UC_{it} + \beta_6 LG_{it} + \varepsilon_{it} \quad (7)$$

$$FP_{it} = \beta_0 + \beta_2 \Delta CP_{it} + \beta_2 age_{it} + \beta_3 size_{it} + \beta_4 LE_{it} + \beta_5 UC_{it} + \beta_6 LG_{it} + F_i + F_f + F_c + \varepsilon_{it} \quad (8)$$

$$FP_{it} = \beta_0 + \beta_1 CM_{it} + \beta_2 \Delta CP_{it} + \beta_3 age_{it} + \beta_4 size_{it} + \beta_5 LE_{it} + \beta_6 UC_{it} + \beta_7 LG_{it} + F_i + F_f + F_c + \varepsilon_{it} \quad (9)$$

4. RESULTS AND DISCUSSION

4.1 Descriptive analysis

Table 3 in summarizes the analysis for companies in Vietnam, Cambodia, the Philippines, and Singapore. Financial indicator is ROS. Environmental indicators include carbon emissions and carbon management. Carbon emissions illustrate the total kg of CO_2 (in scope 2) discharged by the firm. Carbon management shows whether the company has adopted any methods for managing energy waste or CO_2 emissions waste. Firm control variables are size, age, labor efficiency, labor growth, and capacity utilization.

The Return on Sales (ROS) exhibited a mean value of 0.1894, accompanied by a standard deviation of 0.58. The range of ROS is between -16.39 and 0.99, with a total of 1,225 observations.

The initial metric of the carbon performance variable is denoted as ΔCP, which reveals a mean value approximating 22.44 and a standard deviation quantified at 20.64. This statistical framework is further elucidated by its minimum and maximum values of 0 and 98.83, respectively. The subsequent metric pertains to carbon dioxide management, characterized by a mean of 0.42 and a standard deviation of 0.49. The range of these values extends from 0 to 1.

Firm control indicators included LE, LG, CU, size, and age. The index for LE exhibits a range from 0.01 to 1,691.67, yielding a mean value of 15.0793 accompanied by a standard deviation of 55.48996. LG is the index for the growth of the workforce, which shows considerable fluctuation, ranging from -100 to 9,090.91, with a mean of -1.7830 and a standard deviation of 176.41. UC presents a mean of 79.18 and a standard deviation of 23.644, with values extending from 1 to 100. The size of the firm has 975 observations, with a minimum of 5.7, a maximum of 33.27, a mean of 19.63, and a standard deviation of 4.56. Finally, the age variable has 3,123 observations, with the oldest firm being 128 years old and the youngest being 1 year old. The mean and standard deviation for ages is 16.43 and 12.61, respectively.

Table 3. Descriptive statistic table

Variable	N	Mean	Std. deviation	Maximum	Mininum

Firm performance variable					
ROS	1225	0.1894	0.58466	0.99	-16.39
Carbon performance variable					
ΔCP	901	22.4375	20.63896	98.93	0
CM	3123	0.42	0.494	1	0
Firm control variable					
age	3123	16.4297	12.61106	128	1
size	975	19.638	4.576	33.27	5.7
LE	3056	15.0793	55.48996	1691.67	0.01
LG	2928	-1.738	176.41073	9090.91	-100
CU	1195	79.18	23.644	100	1

Table 4 presents the coefficient of correlation, which shows the interrelationships of the variables we selected for the equation. From Table 4, we can observe that the two variables, CP and financial performance, have a positive correlation. As ROS increases, CP will also increase, and vice versa. This is contrary to our research expectation, where we anticipated a negative relationship, meaning that higher CO2 emissions would lead to a decrease in ROS for businesses. Similarly, ROS has a positive relationship with LE and age, meaning businesses with better labor utilization and a longer lifespan tend to have higher ROS. However, for the CM variable, it aligns with expectation, where CM and ROS have a positive relationship. That is, the more a business focuses on energy control and reducing energy loss, the higher its ROS will be. On the other hand, certain variables show a negative correlation. ROS negatively affects the variables CU, LG, and size, indicating that businesses with larger asset ratios, greater employee growth, and higher production capacities tend to have lower ROS. For environmental variables, such as CP and CM, CP not only has a positive effect on ROS but also on LE, LG, and the size of the business. This shows that businesses with better labor utilization, stronger growth in human resources, and assets tend to have higher CO_2 emissions. Regarding the CM index, it aligns with our research expectation that businesses with efficient energy usage will reduce CO_2 emissions. Furthermore, businesses with good production capabilities and large assets often pay more attention to energy efficiency.

Table 4. Pearson Correlations.

	ROS	ΔCP	CM	Age	Size	LE	LG	CU
ROS	1							
DCP	0.73	1						
CM	0.053	-0.117	1					
Age	0.047*	-0.04*	-0.001***	1				
Size	-0.108	0.125	0.158	-0.217	1			
LE	0.076	0.048*	-0.040*	0.05*	0.123	1		
LG	-0.203	0.007**	-0.03*	-0.007**	0.054	0.014*	1	
CU	-0.024*	-0.085	0.183	-0.1	0.055	0.014*	-0.065	1

4.1.1 Descriptive statics and variable relationship

There is an intimate connection between CP (Carbon Performance) and ROS (Return on Sales). However, it is a positive relationship, which is contrary to the findings of our study. Still, this can be understood and explained by the fact that most of the companies we studied are manufacturers. More importantly, our research focuses on emission scope 2 (also known as electricity-related emissions). Therefore, it can be said that if factories want to expand their business and increase revenue, they need to increase production — and this directly affects CO2 emissions because more electricity is required. This leads to higher emissions and at the same time, ROS also increases

Based on Table 4 and Table 3, we can conclude on the relationship of CU (Capital Utilization) with ROS (Return on Sales) and Emission (DCP). For ROS, the CU variable shows a very weak negative linear relationship (-0.024) that is statistically significant ($p < 0.05$). This suggests a small, statistically reliable tendency for ROS to slightly decrease as capital utilization increases. However, economically, this effect may not be substantial due to the correlation's proximity to zero. On the other hand, the relationship between CU and DCP is weakly negative (-0.085) and not statistically significant ($p > 0.05$). Therefore, there is insufficient evidence from the correlation data to conclude a significant linear relationship between capital utilization and the change in carbon performance.

4.2. Empirical results

The findings derived from the Ordinary Least Squares (OLS) regression analysis are delineated in Table 5. Table 5 elucidates the correlation between carbon performance metrics and firm performance indicators. Among a total of 562 observations, the carbon performance metrics are characterized by the variance between carbon emissions and carbon management strategies. In Table 4, upon closer inspection of the results, we can see that ROS, or return on sales, is calculated by dividing the after-tax profit by the total revenue of company i in year t. For CP, the results are opposite to what we expected; CP shows a positive relationship with ROS, which aligns with the results of previous studies [5]. This indicates that companies with a significant increase in CO_2 scope 2 emissions tend to have higher profitability. Additionally, the CM variable, or carbon management, also shows a clear positive effect on ROS. This is in line with our expectations when conducting this study. It indicates that businesses with measures, or those that focus on using energy efficiently and with consideration, will help increase the company's ROS. For the LE variable, it shows a positive relationship with ROS, meaning that companies that use labor efficiently will increase their profitability. In contrast, LG shows a negative relationship with firm performance. Looking at Table 5, we can see that if a company has growth in the number of employees, it will decrease ROS. As for the size variable, it shows a negative relationship, which indicates that if a business has a large total asset value, its ROS will be lower. Although the adjuster R-square is only 0.065, the equation still illustrates the relationship of ΔCP and CM with ROS.

Table 5. Regression analysis on ROS

Variables	Model 1 (ROS)	Model 2 (ROS)	Model 3 (ROS)	Model 4 (ROS)	Model 5 (ROE)
ΔCP	0.003* (2.52)	0.002* (2.235)		0.002** (2.746)	10.724 (0.808)
CM	0.105* (2.357)		0.091* (2.191)		1371.311* (2.282)
age	0.000 (0.241)	0.001 (0.378)	0.01 (0.311)	-0.001 (-0.585)	49.060* (1.97)
size	-0.017*** (-3.382)	-0.015** (-2.994)	-0.015*** (-3.246)	0.017** (2.681)	-1257.063*** (-8.679)
LE	0.001* (2.555)	0.001** (2.403)	0.001** (2.786)	0.002** (3.769)	12.396 (1.460)
LG	-0.001*** (-5.42)	-0.001*** (-5.470)	-0.001*** (-5.796)	0.000 (-1.288)	-8.806 (-1.141)
UC	-0.001 (-1.029)	-0.001 (-0.637)	-0.001 (-1.281)	0.000 (0.677)	11.439 (0.925)
country fixed factors	No	No	No	Yes	Yes
industry fixed factors	No	No	No	Yes	Yes
fsize fixed factors	No	No	No	Yes	Yes
Adjusted R-square	0.065	0.059	0.059	0.153	0.14
Observations	562	712	812	571	410

$^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

In Model 2, Return on Sales (ROS) is employed as the dependent variable, and fixed effects are consciously omitted to analyze the direct effect of explanatory variables on corporate performance, determined through the profit margin on sales.. Nevertheless, taking into account that the model does not incorporate fixed factors such as industry, country, or firm size, it may inadequately capture the variability in ROS, as reflected by the modest adjusted R-squared coefficient (0.059). In particular, concerning the ΔCP variable, the t-test significance is below 0.05, thereby indicating that this variable is statistically significant and exerts a pronounced positive influence on ROS, suggesting that enhancements in CO_2 emission efficiency correlate with increased profitability. Regarding the LE variable, the findings indicate that this variable also contributes positively to ROS, signifying that firms that optimize labor utilization are likely to attain superior profits. Conversely, the LG variable manifests a detrimental association with firm performance; the regression coefficient $\beta = -0.001$ exhibits a negative sign, thereby indicating that the LG variable adversely affects the dependent variable ROS. In contrast, the age and CU variables are statistically insignificant within the model, suggesting that they do not substantially contribute to elucidating the discrepancies in financial performance.

In Model 3, the analysis further uses Return on Sales (ROS) as the dependent variable to assess the impact of factors related to carbon emissions and corporate operations on profitability. This model includes 812 observations but does not apply fixed factors by country, industry or company size, thus reflecting only the average relationship without controlling for different structural characteristics across groups of companies. The ΔCP variable exhibits a positive coefficient (β = 0.002), signifying that the ΔCP variable exerts a beneficial effect on the ROS variable, indicating that enterprises experiencing a significant increase in scope 2 CO_2 emissions are inclined to demonstrate higher profitability. Furthermore, the CM variable also presents a positive coefficient, corroborating that companies that actively engage in carbon management strategies and utilize energy efficiently are likely to enhance their ROS. Additionally, the LE variable reflects a more pronounced positive association with the ROS variable at $p<0.01$, suggesting that the efficient utilization of labor—specifically, generating greater revenue per labor unit—contributes to the augmentation of profits. Conversely, the LG variable manifests a negative coefficient (β = -0.001), indicating an adverse relationship with firm performance, which can be interpreted to mean that labor expansion, in the absence of productivity enhancements, will diminish ROS. Regarding the size variable, it similarly reveals a negative correlation, suggesting that if a firm possesses a substantial total asset value, its ROS is likely to be lower. In model 3, the two variables age and CU persist as statistically insignificant within the model. Although the adjusted R-square is merely 0.059, the equation still elucidates the relationship between ΔCP and CM with ROS.

Model 4 utilizes Return on Sales (ROS) as the dependent variable. This configuration incorporates fixed effects for industry (Fi), firm size (Ff), and country (Fc) to account for unobserved heterogeneity among firms operating across diverse sectors, scales, and national contexts. The integration of these fixed parameters augments the model's explanatory capacity, as evidenced by the elevation of the adjusted R-square to 0.153. The coefficient associated with the carbon performance variable (ΔCP) remains positive, corroborating prior research that indicates an association between increases in scope 2 CO_2 emissions and heightened profitability. This finding may signify the characterization of emissions as a by-product of augmented operations or elevated output levels. The carbon management variable (CM) retains a positive coefficient; however, it loses its statistical significance in this specific model, potentially attributable to the explanatory variance being absorbed by the fixed effects. Labor efficiency (LE) persists in demonstrating a positive and statistically significant influence on ROS, implying that firms exhibiting more effective labor utilization are likely to attain superior profitability based on sales metrics. Conversely, labor growth (LG) no longer maintains statistical significance, suggesting that mere headcount expansion does not correlate with profitability when structural characteristics are accounted for. Importantly, the coefficient for firm size transitions to a positive and significant value, reversing its sign from earlier models. This alteration implies that, when controlling for fixed differences, larger firms may achieve higher ROS, potentially due to economies of scale or enhanced operational efficiencies.

In Model 5, the analysis turns to Return on Equity (ROE) as the dependent variable, capturing the firm's capacity to generate returns on shareholders' equity. As with Model 4, this model incorporates fixed effects to control for structural heterogeneity across firms. The adjusted R-square reaches 0.14, indicating an improved model fit compared to earlier specifications without fixed effects. The CM variable exhibits a consistently positive coefficient that remains statistically significant at the conventional 5% level (β = 1371.311, t = 2.282), suggesting that firms engaging in active carbon management practices tend to yield higher equity-based returns. This finding aligns with the theoretical expectation that environmental responsibility can enhance long-term financial performance. In contrast, the ΔCP variable is not statistically significant (β = 10.724, t = 0.808), implying that the volume of CO_2 emissions alone may not consistently influence equity profitability. A particularly notable result is the firm size coefficient, which is strongly negative and highly significant (β = –1257.063, t = –8.679, $p < 0.001$), indicating that larger firms tend to have lower ROE, possibly due to higher capital intensity or diminishing marginal returns on equity. Neither LE nor LG exhibit statistically significant effects on ROE in this model, suggesting that labor-related factors have limited influence on shareholder returns once firm-specific fixed effects are considered. The inclusion of fixed factors (Fi, Ff, Fc) ensures that the estimated relationships remain robust to variations in industry dynamics, firm scale, and national operating environment.

The incorporation of fixed factors in Models 4 and 5 signifies a pivotal methodological evolution in contrast to Models 1, 2, 3, which are characterized by pooled OLS regressions devoid of fixed effects. The core difference lies in their ability to control for unobserved heterogeneity. While Models 1, 2, and 3 merely provide average relationships between variables, neglecting inherent structural characteristics of individual firms, industries, or countries, Models 4 and 5 actively address this issue

Emphasis must be placed on the enhanced reliability and explanatory power of the models. In Models 1, 2, and 3, the Adjusted R-squared values remained low (ranging from 0.059 to 0.065), indicating that they explained only a small fraction of the variance in ROS. Conversely, with the inclusion of industry, size, and country fixed effects, Models 4 and 5 significantly improved their explanatory power, with Adjusted R-squared values surging to 0.153 and 0.14 respectively. This evidences that a considerably greater segment of the variance associated with the dependent variable is now elucidated by the models, attributable to the regulation of unmeasured yet persistently impactful factors.

Furthermore, the addition of fixed effects dramatically altered the coefficient estimates of other variables. In Model 4, the CM variable lost its statistical significance, suggesting that its initial positive relationship might have been influenced by fixed effects. More notably, the "size" variable reversed its sign from negative to positive and became statistically significant, implying that, when fundamental characteristics are controlled for, larger companies might achieve higher ROS. Similarly, in Model 5 (with ROE), the "size" variable exhibited a strong negative relationship, indicating that larger companies tend to have lower ROE when fixed effects are considered. These changes highlight that initial relationships can be obscured by uncontrolled heterogeneity, and the use of fixed effects provides a more accurate insight into the true impact of each variable.

5. CONCLUSION

This research investigates the effects of carbon dioxide emissions and their management on corporate performance across four ASEAN countries—Vietnam, Cambodia, the Philippines, and Singapore—employing Ordinary Least Squares (OLS) regression analysis.

The findings reveal an unexpected yet notable positive association between carbon emissions and Return on Sales (ROS) in the short term, particularly within carbon-intensive sectors characterized by lenient regulatory frameworks (Lewandowski, 2017). Nonetheless, this correlation may weaken or even reverse as environmental regulations intensify, indicating that emission policies have the potential to generate both pressure and opportunities for long-term financial realignment. Furthermore, the analysis suggests that firms do not invariably experience financial detriment under emission regulations; on the contrary, entities that proactively adopt carbon management initiatives, such as improvements in energy efficiency and reductions in waste, are more likely to attain elevated profitability. This implies that compliance with emission standards, when strategically approached, can enhance rather than impede financial performance. Lastly, the findings confirm that proactive management of emissions can act as a source of competitive advantage. Organizations that allocate resources to sustainable practices not only conform to regulatory requirements but also enhance operational efficiency and brand equity—particularly in nations with more developed environmental policies. In summary, the study emphasizes that while emissions may temporarily correlate with financial benefits in rapidly expanding industries, it is comprehensive and forward-thinking emissions management that yields enduring economic and environmental advantages.

REFERENCES

Al-Tuwaijri, S. A., Christensen, T. E., & Hughes, K. E. (2004). The relations among environmental disclosure, environmental performance, and economic performance: A simultaneous equations approach. Accounting, Organizations and Society, 29(5–6), 447–471. https://doi.org/10.1016/S0361-3682(03)00032-1

Al-Tuwaijri, S. A., Christensen, T. E., & Hughes, K. E. II (2004). “The relations among environmental disclosure, environmental performance, and economic performance: A simultaneous equations approach.” Accounting, Organizations and Society, 29(5-6), 447–471. https://doi.org/10.1016/S0361-3682(03)00032-1

Alvarez, I. G. (2012). Impact of CO 2 Emission Variation on Firm Performance. Business Strategy and the Environment, 21(7), 435–454. https://doi.org/10.1002/bse.1729

Assi, Ala Fathi,(2024) . “Exploring the Dynamic Connection between Financial Performance on Carbon Emissions in BRI Countries.” 2024 International Conference on Decision Aid Sciences and Applications (DASA), 11 Dec. 2024, pp. 1–8, ieeexplore.ieee.org/abstract/document/10836490, https://doi.org/10.1109/dasa63652.2024.10836490. Accessed 9 Apr. 2025.

Aydıngülü Sakalsız, S., & Özçelik, M. (2024). The Impact of Firms’ Carbon Emissions on Financial Performance and the Role of Innovation: Evidence from Türkiye. Mehmet Akif Ersoy Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi. https://doi.org/10.30798/makuiibf.1414190

Brooks, C., & Oikonomou, I. (2018). The effects of environmental, social and governance disclosures and performance on firm value: A review of the literature in accounting and finance. The British Accounting Review, 50(1), 1–15. https://doi.org/10.1016/j.bar.2017.11.005

Brooks, C., & Oikonomou, I. (2018). The effects of environmental, social and governance disclosures and performance on firm value: A review of the literature in accounting and finance. In British Accounting Review (Vol. 50, Issue 1, pp. 1–15). Academic Press. https://doi.org/10.1016/j.bar.2017.11.005

Busch, T., Bassen, A., Lewandowski, S., & Sump, F. (2020). Corporate carbon and financial performance revisited. Organization & Environment, 1–18. https://doi.org/10.1177/1086026620935638

Busch, T., Bassen, A., Lewandowski, S., & Sump, F. (2020). Corporate carbon and financial performance revisited.

Organization & Environment, 1–18. https://doi.org/10.1177/1086026620935638

Busch, T., Bassen, A., Lewandowski, S., & Sump, F. (2020). Corporate Carbon and Financial Performance Revisited. Organization and Environment, 35(1), 154–171. https://doi.org/10.1177/1086026620935638

Chieh-Tse Hou, T., Tran, N. H., Msefula, G., & Dlamini, N. N. (2024). Corporate Carbon Emissions and Firm Performance in South Africa. Review of Integrative Business and Economics Research, 14, 55.

Delmas, M. A., Nairn-Birch, N., & Lim, J. (2015). Dynamics of environmental and financial performance: The case of greenhouse gas emissions. Organization & Environment, 28(4), 374–393. https://doi.org/10.1177/1086026615620238

Delmas, M. A., Nairn-Birch, N., & Lim, J. (2015). Dynamics of Environmental and Financial Performance: The Case of Greenhouse Gas Emissions. Organization and Environment, 28(4), 374–393. https://doi.org/10.1177/1086026615620238

Desai, R., & Raval, A. (2022). Examining the relation between market value and CO_2 emission: Study of Indian firms. Copernican Journal of Finance & Accounting, 11(3), 9–25. https://doi.org/10.12775/CJFA.2022.011

Desai, R., & Raval, A. (2022). Examining the relation between market value and CO_2 emission: Study of Indian firms. Copernican Journal of Finance & Accounting, 11(3), 9–25. https://doi.org/10.12775/CJFA.2022.011

Desai, R., & Raval, A. (2022). EXAMINING THE RELATION BETWEEN MARKET VALUE AND CO_2 EMISSION: STUDY OF INDIAN FIRMS. Copernican Journal of Finance & Accounting, 11(3), 9–25. https://doi.org/10.12775/cjfa.2022.011

Eccles, R. G. (2012). The impact of corporate sustainability on organizational processes and performance. Harvard Business School Working Paper, No. 12-035

Eccles, R. G., Ioannou, I., Serafeim, G., & Hall, M. (2012). THE IMPACT OF CORPORATE SUSTAINABILITY ON ORGANIZATIONAL PROCESSES AND PERFORMANCE. http://www.nber.org/papers/w17950

Fujii, H., Iwata, K., Kaneko, S., & Managi, S. (2013). Corporate environmental and economic performance of Japanese manufacturing firms: Empirical study for sustainable development. Business Strategy and the Environment, 22(3), 187–201. https://doi.org/10.1002/bse.1747

Fujii, H., Iwata, K., Kaneko, S., & Managi, S. (2013). Corporate Environmental and Economic Performance of Japanese Manufacturing Firms: Empirical Study for Sustainable Development. Business Strategy and the Environment, 22(3), 187–201. https://doi.org/10.1002/bse.1747

Gajdosikova, Dominika, et al. "The Relevance of Sectoral Clustering in Corporate Debt Policy: The Case Study of Slovak Enterprises." Administrative Sciences, vol. 14, no. 2, 1 Feb. 2024, p. 26, www.mdpi.com/2076-3387/14/2/26, https://doi.org/10.3390/admsci14020026. Accessed 3 Feb. 2024.

Gallego Álvarez, I., Rodríguez Domínguez, L., & García Sánchez, I. M. (2017). Impact of CO_2 emission variation on firm performance. Business Strategy and the Environment, 26(8), 1232–1246. https://doi.org/10.1002/bse.1974

Ghalda Sabila, et al. "The Effect of Carbon Emission Disclosure and Environmental Performance on Financial Performance." 2022 International Conference on Decision Aid Sciences and Applications (DASA), 11 Dec. 2024, pp. 1–6, https://doi.org/10.1109/dasa63652.2024.10836351.

Greenstone, M., List, J. A., & Syverson, C. (2012). "The effects of environmental regulation on the competitiveness of U.S. manufacturing." NBER Working Paper No. 18392. https://doi.org/10.3386/w18392

Hou, T. C., Tran, N. H., Msefula, G., & Dlamini, N. N. (2023). Corporate carbon emissions and firm performance in South Africa. Sustainability, 15(2), 1605. https://doi.org/10.3390/su15021605

IPCC. (2021). Climate Change 2021 Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf.

Islam, M. S. (2021). Does financial development cause environmental pollution? Empirical evidence from South Asia.

Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-021-16005-8

Islam, M. S. (2022). Does financial development cause environmental pollution? Empirical evidence from South Asia. Environmental Science and Pollution Research, 29(3), 4350–4362. https://doi.org/10.1007/s11356-021-16005-8

Khatib, S. F. A., Ismail, I. H. M., Salameh, N., Abbas, A. F., Bazhair, A. H., & Sulimany, H. G. H. (2023). Carbon emission and firm performance: The moderating role of management environmental training. Sustainability, 15(13), 10485. https://doi.org/10.3390/su151310485

Khatib, S. F. A., Ismail, I. H. M., Salameh, N., Abbas, A. F., Bazhair, A. H., & Sulimany, H. G. H. (2023). Carbon emission and firm performance: The moderating role of management environmental training. Sustainability, 15(4), 3339. https://doi.org/10.3390/su15043339

Khatib, S. F. A., Ismail, I. H. M., Salameh, N., Abbas, A. F., Bazhair, A. H., & Sulimany, H. G. H. (2023). Carbon Emission and Firm Performance: The Moderating Role of Management Environmental Training. Sustainability (Switzerland), 15(13). https://doi.org/10.3390/su151310485

King, A., & Lenox, M. (2002). Exploring the locus of profitable pollution reduction. Management Science, 48(2), 289–299. https://doi.org/10.1287/mnsc.48.2.289.258

King, A., & Lenox, M. (2002). Exploring the Locus of Profitable Pollution Reduction. In Source: Management Science (Vol. 48, Issue 2).

Lee, K. H., Min, B., & Yook, K. H. (2015). The impacts of carbon (CO_2) emissions and environmental research and development (R&D) investment on firm performance. International Journal of Production Economics, 167, 1–11. https://doi.org/10.1016/j.ijpe.2015.05.018

Lee, K.-H., Min, B., & Yook, K.-H. (2015). The impacts of carbon (CO_2) emissions and environmental R&D investment on firm performance. International Journal of Production Economics, 167, 1–11. https://doi.org/10.1016/j.ijpe.2015.05.018

Lewandowski, S. (2017). Corporate Carbon and Financial Performance: The Role of Emission Reductions. Business Strategy and the Environment, 26(8), 1196–1211. https://doi.org/10.1002/bse.1978

Lewandowski, S. (2021). Corporate carbon and financial performance: The role of emission reductions. Business Strategy and the Environment, 30(7), 3196–3213. https://doi.org/10.1002/bse.2804

Makeeva, E., Popov, K., & Teplova, O. (2024). Patenting for profitability: Green energy innovations and firm performance in BRICS countries. Frontiers in Environmental Science, 12, 1332792. https://doi.org/10.3389/fenvs.2024.1332792

Makeeva, E., Popov, K., & Teplova, O. (2024). Patenting for profitability: green energy innovations and firm performance in BRICS countries. Frontiers in Environmental Science, 12. https://doi.org/10.3389/fenvs.2024.1332792

Marin, G., Marino, M., & Pellegrin, C. (2017). The Impact of the European Emission Trading Scheme on Multiple Measures of Economic Performance. Environmental and Resource Economics, 71(2), 551–582. https://doi.org/10.1007/s10640-017-0173-0

Marin, G., Marino, M., & Pellegrin, C. (2021). The impact of the European Emission Trading Scheme on multiple measures of economic performance. Environmental and Resource Economics, 78(3), 737–769. https://doi.org/10.1007/s10640-021-00549-w

Martin, R., Muûls, M., de Preux, L. B., & Wagner, U. J. (2014). Industry compensation under relocation risk: A firm-level analysis of the EU Emissions Trading Scheme. American Economic Review, 104(8), 2482–2508. https://doi.org/10.1257/aer.104.8.2482

Miah, M. D., Hasan, R., & Usman, M. (2021). Carbon emissions and firm performance: evidence from financial and non-financial firms from selected emerging economies. Sustainability (Switzerland), 13(23). https://doi.org/10.3390/su132313281

Miah, M. D., Hasan, R., & Usman, M. (2022). Carbon emissions and firm performance: Evidence from financial and non-financial firms from selected emerging economies. Sustainability, 14(3), 1585. https://doi.org/10.3390/su14031585

MTHEC RU Saskia van Butselaar s4482093 - Master's Thesis . (2020).

Porter, M. E., & Linde, C. van der. (1995). Toward a New Conception of the Environment-Competitiveness Relationship. Journal of Economic Perspectives, 9(4), 97–118. https://www.aeaweb.org/articles?id=10.1257/jep.9.4.97

Preston, C. (2005). IEA GHG Weyburn CO_2 Monitoring and Storage Project: Summary report 2000–2004. Petroleum Technology Research Centre. https://ieaghg.org/docs/General_Docs/Reports/WeyburnSummaryReport_2000-2004.pdf

Preston, C., Monea, M., Jazrawi, W., Brown, K., Whittaker, S., White, D., Law, D., Chalaturnyk, R., & Rostron, B. (2005). IEA GHG Weyburn CO_2 monitoring and storage project. Fuel Processing Technology, 86(14–15), 1547–1568. https://doi.org/10.1016/j.fuproc.2005.01.019

Preston, C., Monea, M., Jazrawi, W., Brown, K., Whittaker, S., White, D., Law, D., Chalaturnyk, R., & Rostron, B. (2005). IEA GHG Weyburn CO_2 monitoring and storage project. Fuel Processing Technology, 86(14–15), 1547–1568. https://doi.org/10.1016/j.fuproc.2005.01.019

Sakalsız, S. A., & Özçelik, M. (2023). The impact of firms' carbon emissions on financial performance and the role of innovation: Evidence from Türkiye. Sustainability, 15(14), 10892. https://doi.org/10.3390/su151410892

Tuesta, Y. N., Crespo Soler, C., & Ripoll Feliu, V. (2020). The influence of carbon management on the financial performance of European companies. Sustainability, 12(12), 4951. https://doi.org/10.3390/su12124951

Tuesta, Y. N., Soler, C. C., & Feliu, V. R. (2020). The influence of carbon management on the financial performance of European companies. Sustainability (Switzerland), 12(12). https://doi.org/10.3390/SU12124951

Van Butselaar, S. (2020). The effect of carbon emissions on firm performance and the moderating effect of innovation [Master's thesis, Radboud University].

van Emous, R., Krušinskas, R., & Westerman, W. (2021). Carbon emissions reduction and corporate financial performance: the influence of country-level characteristics. Energies, 14(19). https://doi.org/10.3390/en14196029

van Emous, R., Krušinskas, R., & Westerman, W. (2023). Carbon emissions reduction and corporate financial performance: The influence of country-level characteristics. Sustainability, 15(3), 2457. https://doi.org/10.3390/su15032457

Wang, W., & Zhang, Y. J. (2022). Does China's carbon emissions trading scheme affect the market power of high-carbon enterprises? Energy Economics, 108. https://doi.org/10.1016/j.eneco.2022.105906

Wang, W., & Zhang, Y.-J. (2023). Does China's carbon emissions trading scheme affect the market power of high-carbon enterprises? Energy Economics, 125, 106885. https://doi.org/10.1016/j.eneco.2023.106885

Zhang, B., Wang, Z., Yin, J., & Su, L. (2012). CO 2 emission reduction within Chinese iron & steel industry: Practices, determinants and performance. Journal of Cleaner Production, 33, 167–178. https://doi.org/10.1016/j.jclepro.2012.04.012

Zhang, B., Wang, Z., Yin, J., & Su, L. (2016). CO_2 emission reduction within Chinese iron & steel industry: Practices, determinants and performance. Journal of Cleaner Production, 103, 151–166. https://doi.org/10.1016/j.jclepro.2014.12.054

Zhou, B., Zhang, G., & Bi, S. (2022). How does emissions trading affect the efficiency of enterprise resource allocation? Evidence from China. Journal of Environmental Management, 321, 115854. https://doi.org/10.1016/j.jenvman.2022.115854

Zhou, B., Zhang, G., & Bi, S. (2023). How Does Emissions Trading Affect the Efficiency of Enterprise Resource Allocation? Evidence From China. SAGE Open, 13(4). https://doi.org/10.1177/21582440231212040