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# Greenhouse Gas Emissions as a Strategic Financial Variable: A Systematic Literature Review and Bibliometric Analysis of the Manufacturing Industry

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**ABSTRACT**

Climate change has intensified regulatory pressure and market expectations for corporate decarbonization, particularly in carbon-intensive sectors such as manufacturing. Although numerous empirical studies have examined the relationship between greenhouse gas (GHG) emissions and financial performance, findings remain fragmented and sometimes divergent, creating uncertainty regarding the conditions under which emissions influence firm outcomes. This study synthesizes empirical evidence on the relationship between GHG emissions and financial performance in manufacturing firms through a systematic literature review of 16 studies published between 2019-2025, complemented by bibliometric analysis using VOSviewer to identify thematic clusters, research density, and temporal evolution. The results reveal a shift from treating emissions as environmental externalities toward conceptualizing them as strategic variables embedded within firm-level economic systems. Positive financial outcomes are more frequently observed when emission reduction aligns with efficiency improvements and technological progress, whereas short-term accounting effects and market-based responses may diverge depending on regulatory design and institutional context. The evidence indicates that the financial implications of carbon-related mechanisms are conditional on governance quality, policy design, market maturity, and performance measurement. These findings provide an integrative, contingency-oriented understanding of how decarbonization interacts with firm performance across heterogeneous institutional settings.

## INTRODUCTION

Climate change represents one of the most critical structural challenges of the 21st century. The continued increase in greenhouse gas (GHG) concentrations, particularly carbon dioxide ($CO_2$), has intensified global warming and generated substantial ecological, economic, and social consequences [19]. Among industrial actors, the manufacturing sector occupies a pivotal position in this trajectory, accounting for approximately 24–25% of global $CO_2$ emissions in 2020 according to the International Energy Agency (IEA). Consequently, manufacturing firms are increasingly positioned at the center of regulatory intervention and sustainability-driven market expectations.

In response to escalating global pressure, governments have introduced progressively stringent climate instruments, including carbon trading mechanisms (CTM), carbon taxes, and emission trading systems (ETS) [21]. These policy instruments are designed to internalize environmental externalities and reconfigure corporate incentives through market-based mechanisms. As a result, greenhouse gas emissions previously regarded primarily as environmental externalities have evolved into strategic variables embedded within corporate financial and operational systems [30]. Firms are no longer evaluated solely by operational efficiency and profitability, but also by carbon exposure, regulatory compliance capacity, environmental transparency, and sustainability positioning.

From a theoretical perspective, market-based climate policies are expected to stimulate innovation, enhance resource efficiency, and strengthen long-term financial performance. However, empirical findings remain inconclusive. Some studies report positive value creation through cost efficiency, technological innovation, reputational enhancement, and improved access to capital [12]. In contrast, other studies identify short-term financial pressures resulting from compliance costs, capital adjustment, and regulatory uncertainty. The rapid expansion of carbon market instruments, including carbon credits and carbon offsets, further complicates this relationship. While these mechanisms create opportunities to monetize emission reductions, their effectiveness in ensuring genuine decarbonization remains contested, particularly considering concerns regarding greenwashing and market credibility [24].

Despite the growing volume of research, a structural gap persists. Much of the existing literature examines isolated mechanisms such as ETS implementation, carbon accounting practices, or voluntary disclosure without offering an integrated explanation of how and under what institutional conditions emissions influence financial performance. This fragmentation limits theoretical consolidation and weakens policy relevance. The need for systematic synthesis becomes increasingly urgent as more countries adopt net-zero commitments and implement stricter carbon regulations [10]. Simultaneously, the expansion of voluntary and compliance carbon markets generates new financial opportunities and systemic risks for firms [31]. Within the broader transition toward a low-carbon economy, the manufacturing sector remains a primary arena of structural transformation [7], underscoring the importance of developing a coherent analytical framework that integrates environmental and financial dimensions.

Accordingly, the central research problem addressed in this study is how and under what institutional and strategic conditions greenhouse gas emissions and carbon-related mechanisms influence the financial performance of manufacturing firms. To address this question, this study conducts a systematic literature review combined with a bibliometric analysis to synthesize empirical findings, identify mediating and moderating mechanisms, examine thematic evolution, and clarify the contingency factors shaping the emission-financial performance nexus across diverse institutional contexts. By consolidating fragmented empirical evidence into an integrated analytical framework, systematically mapping the intellectual structure of carbon-finance scholarship, and advancing a contingency-based explanation of the emission-financial performance relationship, this study contributes to strengthening theoretical coherence, enhancing methodological transparency, and improving policy relevance in understanding how greenhouse gas emissions function as strategic financial variables within the manufacturing industry.

## MATERIALS AND METHODS

This study uses the Systematic Literature Review (SLR) method combined with bibliometric analysis to identify, evaluate, and synthesize previous empirical studies on the relationship between greenhouse gas emissions and the financial performance of manufacturing companies [27]. A systematic literature review was selected because it allows for a comprehensive, structured, and transparent synthesis of the existing body of knowledge, enabling the identification of patterns, inconsistencies, and research gaps.

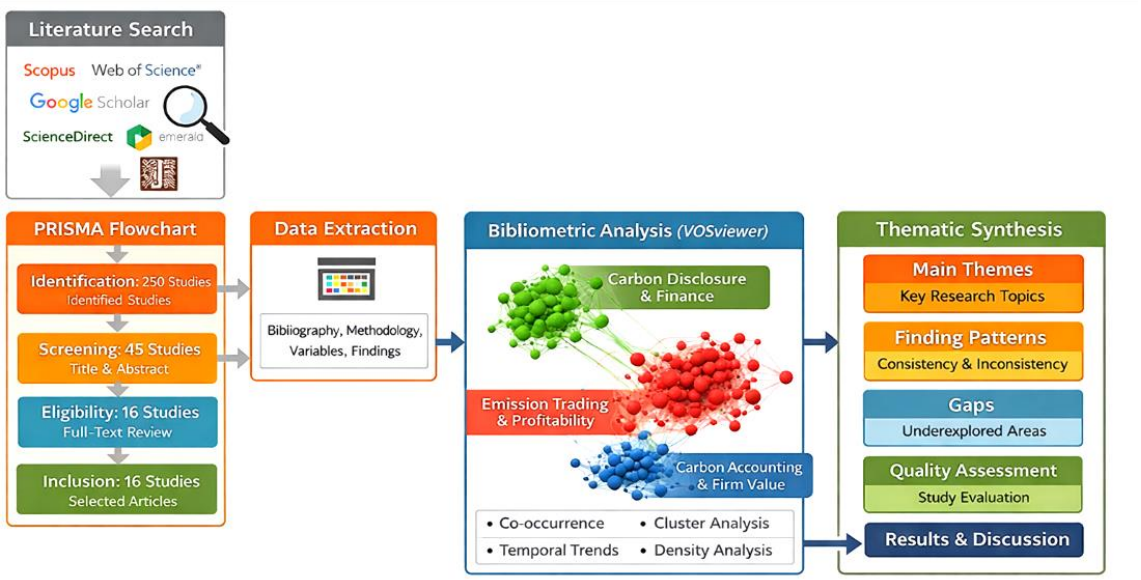



Figure 1. Research Framework

The overall research design and analytical sequence are presented in Figure 1. The research framework illustrates the sequential stages of literature search, PRISMA-based screening, structured data extraction, bibliometric mapping using VOSviewer, and thematic synthesis leading to the results and discussion. The figure clarifies how each methodological component is interconnected within the study.

Literature searches were conducted on several major academic databases, including Scopus, Web of Science, Google Scholar, ScienceDirect, Emerald Insight, and JSTOR [2], to ensure broad coverage of peer-reviewed research. The search keywords consisted of Boolean combinations of environmental, financial, industrial, and policy-related terms, namely "carbon emission" OR "greenhouse gas emission" OR "$CO_2$ emission" AND "financial performance" OR "firm performance" OR "profitability" AND "manufacturing" OR "industrial" AND "carbon market" OR "emission trading" OR "carbon accounting" OR "carbon disclosure." The search period was restricted to publications between 2019-2025 to ensure relevance to the current climate policy context.

To ensure analytical rigor, predefined inclusion and exclusion criteria were applied during the screening and eligibility stages. The detailed criteria are summarized in Table 1. The inclusion criteria required that studies discuss the relationship between greenhouse gas emissions or related variables, such as carbon accounting, carbon disclosure, and emission trading systems (ETS), and firm financial performance. Studies were required to focus on manufacturing industries or industries with high carbon intensity, to apply clear methodological approaches, whether quantitative or mixed

methods, and to be published in peer-reviewed journals or reputable academic conferences, written in either English or Indonesian. The exclusion criteria eliminated studies that addressed only environmental aspects without linking them to financial performance, single case studies without generalizable findings, conceptual studies without empirical validation, duplicate publications where only the most recent versions were retained, and studies with unclear or invalid methodologies [4].

Table 1. Inclusion and Exclusion Criteria

| Criteria | Inclusions | Exclusion |
|---|---|---|
| Topic/Subject | The study discusses GHG or $CO_2$ emissions with the financial performance of manufacturing companies, or related variables (carbon accounting, ETS, carbon disclosure) | Studies focusing solely on environmental aspects without a financial performance linkage |
| Study Type | Empirical (quantitative, qualitative, mixed methods) with a clear methodology | Conceptual studies without empirical validation |
| Publication Type | Peer-reviewed journal articles and reputable conference reports | Books, editorials, opinion papers, and non-peer-reviewed technical reports |
| Time Range | 2019-2025 | Before 2019 |
| Data/Analytics Types | Studies with statistical or quantitative reports or structured qualitative synthesis | Studies without valid data or a statistical basis |
| Full Text Access | Full text available for data extraction | Full text not available |

Sources: [4]

The literature selection process follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol. As illustrated in the research framework in Figure 1, the identification stage yielded 250 potential articles from the selected databases. The screening stage, based on titles and abstracts and removal of duplicates, reduced the number of relevant articles to 45. The eligibility stage involved full-text reading and evaluation based on the predefined inclusion and exclusion criteria, resulting in 16 articles eligible for in-depth analysis. The final inclusion stage involved a comprehensive synthesis and bibliometric analysis of the 16 selected empirical studies [20].

Table 2. Literature Selection Process Based on PRISMA

| PRISMA Stage | Activity Description | Descriptions and References | Records Retained |
|---|---|---|---|
| Identification | Find all articles from databases with predefined keywords (e.g., Scopus, Web of Science, ScienceDirect, Emerald Insight, JSTOR, Google Scholar). | The initial stage of the literature search involved identifying relevant records based on a systematic and comprehensive search strategy. | 250 |

| | | | |
|---|---|---|---|
| Screening (Title & Abstract) | Screening articles against inclusion and exclusion criteria based on titles and abstracts. Irrelevant articles are removed. | Screening is carried out to remove articles that are clearly not on topic without reading the full text, as well as separating duplicate articles. | 45 |
| Eligibility | Full text review of articles that pass the screening stage to ensure compliance with inclusion/exclusion criteria. | At this stage, the researcher assesses in more detail whether the article has data/findings that are really relevant to the research RQ. | 16 |
| Final Inclusion | Studies that passed the eligibility stage were included for data extraction and bibliometric analysis as well as thematic synthesis. | Articles that actually meet all the criteria are pulled as final literature for further analysis. | 16 |

Sources: [20]

For each included article, data were systematically extracted, including bibliographic information such as authors, year of publication, title, and journal or conference source. The research context covered country or region, industry focus, and study period [25]. The purpose of the research included research questions or hypotheses. Methodological information included research design, analytical methods, and sample size [20]. Extracted variables cover dependent, independent, moderating, mediating, and control variables. Key findings and empirical conclusions were recorded [26], along with limitations acknowledged by the authors. All extracted data were organized in a synthesis matrix to facilitate structured comparison across studies.

Bibliometric analysis was performed using VOSviewer version 1.6.20 to identify key thematic structures within the selected literature. Co-occurrence analysis was conducted to identify keywords that most frequently appear together, thereby revealing dominant themes and research topics [18]. Cluster analysis was used to group related keywords into thematic streams [22]. Temporal analysis examined the development of research themes over time, identifying shifts in scholarly focus [3]. Density analysis was applied to identify areas of high research intensity and underexplored topics [3]. The VOSviewer parameters included a minimum keyword occurrence threshold of 3, the use of full counting, association strength normalization, and layout settings with attraction = 2 and repulsion = 1 [14]. All visual outputs were exported in high-resolution format (minimum 300 dpi) to ensure clarity and scientific presentation quality.

Following the bibliometric analysis, thematic synthesis was conducted to identify recurring patterns across empirical findings. The analysis examined consistency and inconsistency in results, mechanisms describing how relationships between emissions and financial performance operate [8], and contingency factors influencing the strength or direction of these relationships [32]. Research gaps and underexplored areas were also identified. The synthesis was conducted iteratively by comparing findings across the 16 selected studies to ensure systematic and evidence-based interpretation.

## RESULTS AND DISCUSSIONS

### Results

This section synthesizes findings from the 16 empirical studies selected through the PRISMA procedure described in the Materials and Methods section. The studies were conducted in Indonesia, China, India, Nigeria, and multi-country contexts. Methodological approaches include multiple linear regression, fixed-effect and instrumental variable panel estimation, Difference-in-Differences (DID), DEA combined with mediation analysis, PSM-DID, triple-difference estimation, pooled OLS, random effects models, panel regression, quasi-experimental DID, and mixed methods. The empirical domains examined across the corpus comprise emission reduction, carbon productivity, voluntary carbon disclosure (CED/CSR), carbon accounting, carbon credits, Emission Trading Systems (ETS), carbon cost exposure, and carbon price volatility, with financial performance proxied by ROA, ROE, Tobin's Q, sales, profit decomposition, market-to-book ratio, investment efficiency, and financial risk.

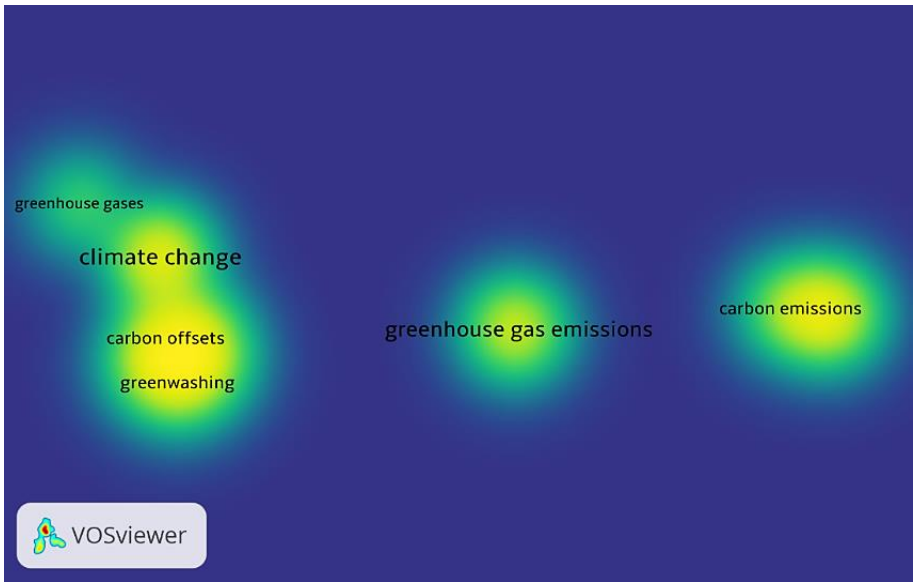



Figure 2. Density Visualization of Keyword Co-Occurrence.
Color Intensity Indicates Keyword Concentration and Relational Density.

The density visualization indicates a structured core-periphery configuration within the selected literature. Foundational terms such as climate change and greenhouse gases occupy central density positions, reflecting their cross-cutting relevance across empirical contexts. Surrounding these conceptual anchors, greenhouse gas emissions and carbon emissions form a denser analytical layer connecting macro-environmental discourse with firm-level operational metrics. More specialized constructs, including carbon offsets, net zero, carbon transition, sustainability ratings, and greenwashing, appear as concentrated yet relatively segmented nodes, suggesting thematic differentiation rather than fragmentation. This configuration reflects increasing analytical specificity while maintaining conceptual continuity.

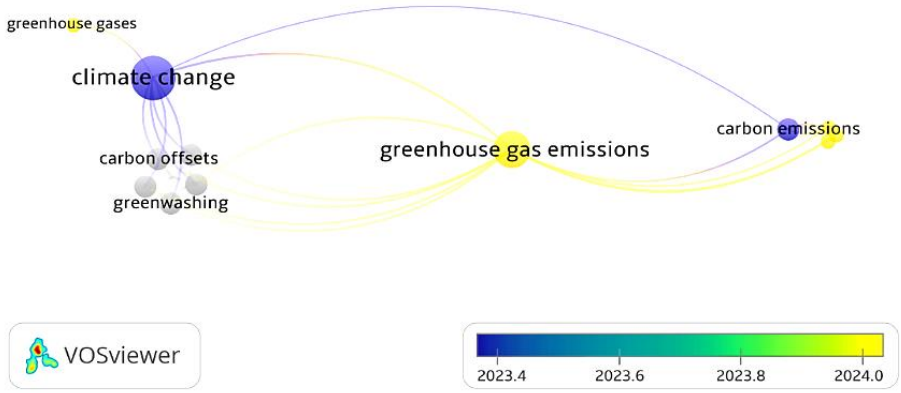



Figure 3. Overlay Visualization of Research Theme Evolution.
Color Gradients Represent the Average Publication Year.

Temporal overlay mapping reveals progressive thematic layering. Earlier studies emphasize macro-conceptual framing of climate change and greenhouse gases. Subsequent research increasingly operationalizes emissions through measurement-oriented constructions such as greenhouse gas emissions and carbon emissions. More recent contributions shift toward governance and instrument-based mechanisms, including carbon offsets, disclosure practices, and greenwashing concerns. The evolution demonstrates a transition from conceptualization to quantification and subsequently to policy and governance evaluation, consistent with the maturation of carbon regulation frameworks during the review period.

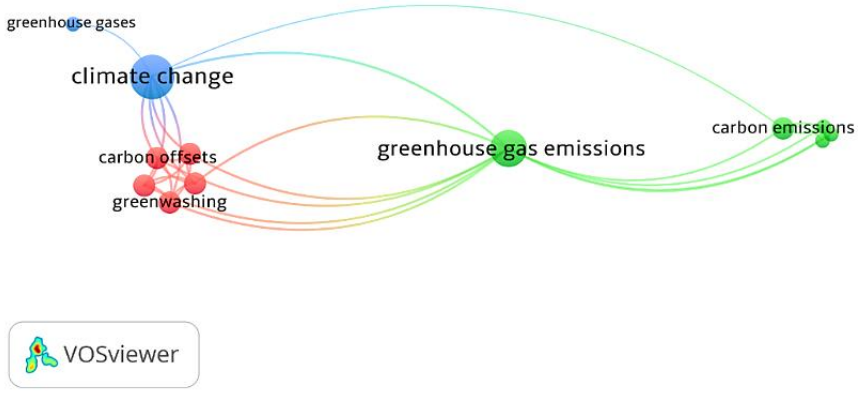



Figure 4. Network Visualization of Keyword Co-Occurrence.
Node Size Reflects Keyword Frequency and Link Strength Indicates Thematic Relationships (n = 16).

The network visualization identifies greenhouse gas emissions as a bridge construct linking macro-level climate discourse with instrument-specific mechanisms.

Climate change occupies a central anchoring position, directly connected to greenhouse gases, carbon offsets, and greenwashing. Carbon emissions appear as a more specialized node associated with quantification and implementation domains. The relational structure indicates that empirical research does not treat emissions solely as environmental outcomes but integrates them with governance instruments and financial performance mechanisms.

Table 3 presents a structured synthesis of the 16 eligible empirical studies. The studies span Indonesia, China, India, Nigeria, and multi-country settings, with methodological diversity including regression-based panel models, DID-based quasi-experiments, DEA, and mixed methods. The variables include carbon accounting, ETS, voluntary disclosure, carbon credits, carbon costs, carbon productivity, and price volatility, alongside financial performance indicators such as ROA, ROE, Tobin's Q, sales, profit, market-to-book ratio, and financial risk.

Table 3. Eligible Articles Summary

| Study Title | Ref | Purpose | Methodology | Variabel | Analysis Results |
|---|---|---|---|---|---|
| Profit decomposition: $CO_2$ reduction | [23] | Analyze $CO_2$ trading to profit (revenue & cost) | Multiple linear regression | D: income; ID: carbon emissions; K: investment, enterprise, and export | Emissions reductions rise, revenues fall, and profits rise |
| Carbon offsets: decarb or washing? | [9] | Investigation of carbon offsets and their effects | ESG Sustainalytics dan DID | Offset credits, quality of projects, scope 1 emissions, and ESG | Cheap offsets do not have a significant impact on reducing emissions, and carbon offsets become greenwashing media |
| Voluntary carbon disclosure in Indonesia | [17] | The impact of voluntary disclosure on efficiency & ROA | Regression of the data panel | D: Tobin's Q, ROA, and Investment efficiency; ID: CED | Disclosure: ROA (down), efficiency (up) |

| Study Title | Ref | Purpose | Methodology | Variabel | Analysis Results |
|---|---|---|---|---|---|
| Carbon costs & firm performance | [1] | Impact of carbon cost and the impact of heterogeneity | FE-IV panel | D: sales, ROA, and investment; ID: carbon cost | Carbon cost does not reduce performance, except for employment |
| ETS & emission efficiency (Chinese cities) | [5] | Impact of ETS on emission levels | DEA + mediasi + DID | D: carbon efficiency; ID: ETS policy; M: technological innovation | ETS: increased efficiency through energy structures and innovation |
| Carbon accounting and firm performance | [28] | The impact of carbon accounting on the environment and finance | Multiple linear regression | D: ROE, emissions, and ROA; ID: application of carbon accounting | Application: environmental and financial performance rise |
| Carbon credits & manufacturing firms | [16] | Carbon credit and the role of GCG/CSR | Pooled OLS | D: performance of finance; ID: carbon credits; M: GCG and CSR | Carbon credits: moderated from CSR/GCG and performance from finance |
| CED & CSR on manufacturing firms | [15] | The influence of CED and CSR on ROA | Panel regression | D: ROA; ID: CSR and CED | Individuals have no significance and are simultaneously significantly |

| Study Title | Ref | Purpose | Methodology | Variabel | Analysis Results |
|---|---|---|---|---|---|
| ETS & Financial Performance (China) | [11] | The impact of ETS on financial performance | Quasi-experimental DID | D: Tobin's Q and ROA; ID: ETS; M: law | ETS: ROA increased, Tobin's Q decreased, and non-operating revenues increased |
| Carbon reduction and financial performance (India) | [13] | Carbon emission reduction and MBR | Random effect model | D: market to book ratio; ID: carbon productivity | Significant positive relationship between CP & MBR |
| Carbon price volatility & risk | [29] | Price volatility from carbon and financial risks | Fixed impact regression | D: financial risk; ID: price volatility of carbon | Volatility: financial risks rise in large companies |
| ETS: carbon reduction & pollution | [6] | Synergistic impact of ETS on $CO_2$ and pollution | DID mediation and timing | D: $CO_2$, $PM_{2.5}$, and $SO_2$; ID: ETS | ETS: $CO_2$ down 19.2%, $PM_{2.5}$ down 6.4%, and $SO_2$ down 60.9% |
| Feasibility of ETS in different economies | [33] | The impact of the ETS on $CO_2$ and GDP in heterogeneous contexts | PSM-DID dan triple diff | D: GHG and GDP emissions | ETS: $CO_2$ down 10%, GDP increased 6.4%, stronger than developed provinces |
| ETS and technological progress | [30] | ETS and growth rate in GTFP industrial | DID multi-period | D: GTFP, TC, EC; ID: dummy ETS | ETS: an increase in GTFP of 8.5%, and |

| Study Title | Ref | Purpose | Methodology | Variabel | Analysis Results |
|---|---|---|---|---|---|
| | | subsectors | | | especially on via TC of 17.5% |
| Voluntary carbon offsets: market study | [35] | Structure and dynamics of the carbon offset market | Mixed method | Vol: vintage, offset, and country; Qualitative: Market Challenge | Challenges in terms of quality, transparency, and visibility of offset pricing |
| Carbon emission and accounting in Nigeria | [34] | Influence of factors impacting manufacturing performance (accounting and emissions) | Panel fixed effect | D: ROA and ROE; ID: accounting and emissions | Negative emissions on ROE, accounting information is not very significant |

Description: D: dependent variable; M: the moderation or mediation variable; ID: independent variable; K: control variable

**Discussions**

The reviewed evidence indicates that the relationship between carbon emissions and financial performance is conditional and context-dependent. Positive associations are documented where emission reduction aligns with productivity improvements or innovation gains ([23], [13]) and where ETS induces efficiency and technological progress ([5], [30], [33]). However, voluntary disclosure may reduce short-term accounting performance ([17], [15]), and ETS may generate divergent market responses, as reflected in the difference between ROA and Tobin's Q in [11]. These findings suggest that financial outcomes depend on time horizon and performance metric rather than emission reduction alone.

Carbon accounting exhibits differentiated effects. Study [28] reports improvements in ROA and ROE following implementation, whereas [34] finds insignificant effects in Nigeria. This contrast indicates that informational mechanisms may depend on institutional credibility and the reporting environment. ETS-related evidence consistently documents improvements in emission efficiency and technological indicators ([5], [6], [30], [33]). However, the mixed financial response identified in [11] highlights divergence between operational efficiency and market valuation. This suggests

that investor perception may respond differently to accounting-based performance indicators.

Studies on carbon credits and offsets ([9], [35]) emphasize quality, transparency, and greenwashing concerns. Study [16] shows that CSR and GCG moderate financial outcomes, indicating that internal governance structures influence performance effects. Carbon price volatility increases financial risk exposure ([29]), adding a risk dimension to the performance discussion. Carbon cost does not uniformly reduce firm performance except in employment ([1]), indicating heterogeneity across impact channels. Regional heterogeneity is also observed in ETS effectiveness [33].

To strengthen the analytical positioning of the present findings within the broader empirical landscape, a structured comparative synthesis of the reviewed studies is provided in Table 4. This comparison systematically evaluates differences in institutional contexts, policy instruments, financial indicators, and conditioning mechanisms, enabling clearer identification of converging patterns and sources of divergence across literature.

Table 4. Structured Comparison of Empirical Evidence on Carbon Mechanisms and Financial Performance

| Study | Context | Policy / Instrument | Financial Outcome | Effect Direction | Conditioning Mechanism | Implication Relative to the Present Study |
|---|---|---|---|---|---|---|
| [23]; [13] | Indonesia; India | Emission reduction & productivity | Increased profit & market valuation | Positive (long-term) | Cost efficiency; innovation | Support value-creation under productivity gains |
| [17]; [15] | Indonesia | Voluntary disclosure (CED, CSR) | Decline in ROA (short-term) | Negative (short-term) | Reporting burden; limited incentives | Confirm the temporal trade-off dynamic |
| [28] | Indonesia | Carbon accounting | Improved ROA & ROE | Positive | Transparency; signaling effect | Support mediation via information quality |
| [34] | Nigeria | Carbon accounting | Insignificant financial | Context-dependent | Institutional weakness | Highlight governance |

| Study | Context | Policy / Instrument | Financial Outcome | Effect Direction | Conditioning Mechanism | Implication Relative to the Present Study |
|---|---|---|---|---|---|---|
| | | | effect | | | contingency |
| [5]; [6]; [30]; [33] | China | ETS implementation | Emission efficiency & productivity gains | Positive (operational) | Technological change; energy restructuring | Reinforce the innovation-inducement pathway |
| [11] | China | ETS | ROA ↑; Tobin's Q ↓ | Ambivalent | Market perception vs accounting returns | Reveal divergence between accounting & market metrics |
| [9]; [35] | Global voluntary market | Carbon offsets | Limited emission reduction impact | Conditional | Market integrity; additionality issues | Stress need for governance quality |
| [16] | Manufacturing | Carbon credits | Moderated performance impact | Conditional | CSR; GCG | Confirm internal capability moderation |
| [29] | Large firms | Carbon price volatility | Increased financial risk | Negative (risk dimension) | Market uncertainty exposure | Extend performance analysis to risk |
| [1] | Multi- | Carbon | No | Neutral | Cost | Confirm |

| Study | Context | Policy / Instrument | Financial Outcome | Effect Direction | Conditioning Mechanism | Implication Relative to the Present Study |
|---|---|---|---|---|---|---|
| | country | cost | general performance decline | | absorption capacity | heterogeneity across firms |
| Present Study | Multi-context synthesis | Integrated carbon mechanisms | Context-dependent financial impact | Nonlinear & contingent | Governance quality; institutional maturity; innovation; CSR; ETS design | Develop an integrative contingency-based framework |

The structured comparison indicates three consistent patterns. First, positive financial effects are more frequently observed when emission policies are associated with efficiency improvements or technological progress. Second, short-term negative or neutral effects emerge under compliance-driven or weak institutional contexts. Third, financial outcomes are frequently mediated or moderated by governance structures, institutional quality, market maturity, and performance measurement type.

These patterns suggest that variation in prior findings reflects contextual and methodological differences rather than empirical contradiction. By consolidating operational efficiency, market-based valuation, governance mechanisms, and risk exposure within a contingency-oriented synthesis, this study integrates fragmented evidence without asserting uniform causality. The findings indicate that innovation-related financial gains depend on institutional stability and firm capability rather than arising automatically from regulation. Divergence between accounting and market indicators underscores the need to distinguish operational efficiency from investor perception in carbon policy evaluation.

From a policy perspective, the evidence suggests that regulatory design, transparency standards, and enforcement quality influence financial outcomes. ETS appears more consistently associated with efficiency improvements when accompanied by technological restructuring. In voluntary markets, verification and additionality standards are central to credibility. From a managerial perspective, emission reduction strategies appear more likely to generate financial value when integrated with governance structures, innovation capacity, and risk management practices rather than treated solely as compliance obligations.

Beyond comparative synthesis, the present review contributes by reframing carbon emissions from a peripheral environmental indicator into a structurally embedded strategic variable within firm-level economic systems. The heterogeneity documented across instruments, regions, and performance metrics indicates that financial outcomes are not determined by emission reduction alone, but by the institutional, governance, and innovation configurations through which decarbonization is operationalized. Divergent empirical findings, therefore, reflect conditional alignment rather than inconsistency. This perspective shifts the analytical focus from asking whether carbon reduction improves financial performance toward examining under which structural conditions, through which mechanisms, and across which performance dimensions such effects materialize. By consolidating fragmented empirical evidence into a contingency-oriented synthesis, this review advances a more integrated understanding of how regulatory design, corporate governance, market dynamics, and firm capabilities jointly shape the economic consequences of decarbonization.

## CONCLUSION

This systematic review synthesizes evidence from 16 empirical studies and demonstrates that carbon emission reduction cannot be interpreted solely as a technical compliance activity. Rather, it operates as a strategic corporate variable with multidimensional implications for cost structures, innovation trajectories, risk exposure, market valuation, and long-term competitiveness. Across contexts, the economic consequences of decarbonization are neither uniformly positive nor uniformly negative; instead, they reflect conditional and context-dependent dynamics shaped by institutional design, governance quality, performance measurement, and firm-level capabilities.

The reviewed studies consistently indicate that positive financial outcomes are more likely to emerge when emission reduction is aligned with productivity improvements, technological upgrading, and efficiency gains. Market-based instruments such as Emission Trading Systems (ETS) demonstrate robust effects on emission efficiency and technological progress, particularly when supported by structural energy adjustments and innovation incentives. However, financial market responses may diverge from accounting-based indicators, highlighting differences between operational efficiency gains and investor expectations. Voluntary disclosure and carbon accounting mechanisms further reveal that information transparency functions as an enabling infrastructure, yet its financial impact depends critically on implementation quality, institutional maturity, and stakeholder credibility.

The synthesis also confirms substantial heterogeneity across performance dimensions, regions, and corporate characteristics. Financial impacts vary between profitability, market-based valuation, employment, and risk exposure. Institutional context plays a decisive role, as evidenced by differences between emerging and more mature regulatory environments. Governance structures, including CSR engagement and corporate governance quality, condition the effectiveness of carbon credit and disclosure strategies. Moreover, carbon price volatility introduces an additional financial risk dimension, extending the evaluation of decarbonization from return generation toward stability and risk management considerations.

Integratively, the evidence supports a conceptual shift from treating emissions as externalities toward recognizing emissions as strategic variables embedded in corporate decision-making and policy architecture. Effective policy design, therefore, requires sensitivity to institutional heterogeneity, credibility of market mechanisms, and alignment

between environmental objectives and innovation incentives. For practitioners, decarbonization strategies are more likely to generate sustainable value when integrated with credible carbon accounting systems, governance reinforcement, green innovation investment, and structured risk management against carbon price fluctuations.

Finally, several research gaps remain evident. The geographical concentration of empirical evidence limited long-term dynamic analysis, narrow performance proxies, and insufficient exploration of interaction effects among policy instruments indicate the need for deeper causal investigation and broader comparative frameworks. By consolidating fragmented empirical findings into a contingency-oriented synthesis, this review contributes to clarifying the structural conditions under which carbon-related mechanisms influence financial performance and provides a foundation for future empirical inquiry grounded in institutional and organizational complexity.

## LIMITATIONS

This review is subject to several limitations that should be acknowledged. First, the generalizability of the findings is constrained by the geographical concentration of the empirical evidence, as a substantial proportion of the reviewed studies were conducted in Asian contexts, particularly China. This regional dominance may limit broader institutional comparability. In addition, methodological heterogeneity, including differences in econometric specifications, model selection, and variable operationalization, restricts direct cross-study comparison and may contribute to variation in reported outcomes. Many studies adopt a short-term analytical horizon, thereby providing an incomplete assessment of long-term structural and financial implications of emission reduction strategies.

Second, the causal mechanisms linking emissions and financial performance remain insufficiently specified. Although associations are documented, the underlying transmission channels, whether through cost restructuring, innovation pathways, signaling effects, or regulatory adaptation, are not consistently disentangled. This limitation is particularly pronounced in developing countries characterized by heterogeneous institutional environments and relatively limited empirical coverage.

Third, the scope of performance indicators remains relatively narrow. Most studies focus primarily on accounting-based and market-based financial metrics, while non-financial dimensions such as innovation performance, employee well-being, and customer-related outcomes receive comparatively limited attention. This concentration may restrict the multidimensional understanding of corporate responses to carbon-related mechanisms.

Finally, temporal dynamics and policy interaction effects remain underexplored. The evolution of emission performance relationships over extended periods has not been sufficiently examined, and limited evidence is available regarding how multiple policy instruments, such as emission trading systems, carbon taxes, and subsidies, interact within the same institutional setting. These limitations highlight the need for longitudinal designs, integrated policy analysis, and broader multidimensional performance frameworks in future research.

## SUGGESTIONS FOR FURTHER RESEARCH

Identified limitations and gaps in the research provide opportunities for future research efforts to develop additional findings. Future research should focus on examining

the long-term effects of emission reduction on the financial performance and temporal dynamics of this relationship by conducting longitudinal studies over extended periods of time. There should also be additional research conducted in different geographical locations (particularly developing/emerging economies) to enhance the overall generalizability of the results obtained in each of the different studies.

Research that uses quasi-experimental or experimental designs to identify causal mechanisms linking emissions and financial performance is needed. Research that explores the impact of emission reduction on other performance dimensions, such as innovation performance, employee welfare, customer satisfaction, or social impact, is needed for a more holistic understanding.

Research into how various policy instruments, such as ETS, carbon taxes, subsidies, and regulations, interact and their synergistic effects or trade-offs is needed. Research on the role of specific technologies such as renewable energy, CCS, circular economy, and digitalization in mediating the emission and financial performance relationship is needed.

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