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Sustainable Corporate Finance and Investments

James Nickolaou

THE FINAL MASTER'S THESIS

Tvarios Tiekimo Grandinės ir Jų Poveikis Įmonės Veiklos Rezultatams	**Sustainable Supply Chains and Their Impact on Corporate Performance**

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SUMMARY IN ENGLISH

VILNIUS UNIVERSITY BUSINESS SCHOOL
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JAMES NICKOLAOU
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This study examines the relationship between SSCM practices and corporate financial performance, with particular attention to environmental sustainability, ESG performance, and GHG emissions. Grounded in the resource-based view, natural resource-based view, stakeholder theory, and institutional theory, the research assesses whether sustainability-related capabilities are associated with improved firm-level financial outcomes. Using a quantitative panel-data approach, the analysis covers ten large multinational firms in Europe and the United States over the period 2016-2024. Bloomberg data include accounting-based performance measures (return on assets, return on equity, and operating margin), overall ESG scores, ESG pillar scores (environmental, social, governance), and GHG emissions across Scope 1, Scope 2 (location-based), and Scope 3. Fixed-effects panel regressions with firm and year effects are employed to control for unobserved heterogeneity and time-specific shocks. The results show that while overall ESG performance and most ESG pillars are positively related to financial performance, these relationships are generally not statistically significant. The governance pillar is an exception, exhibiting a statistically significant negative association with return on equity, suggesting short-term costs related to governance investments or compliance. Analysis of GHG emissions indicates that Scope 2 emissions are positively and significantly associated with financial performance, whereas Scope 1 and Scope 3 emissions show no significant effects. Overall, the results indicate that the financial effects of SSCM and ESG initiatives are context-dependent and tend to materialize over longer time horizons rather than immediately. The findings highlight the importance of disaggregating ESG measures and incorporating temporal dynamics when assessing the relationships between sustainability and performance.

SUMMARY IN LITHUANIAN

VILNIAUS UNIVERSITETO VERSLO MOKYKLA

TVARIŲ VERSLO FINANSŲ IR INVESTICIJŲ PROGRAMA

JAMES NICKOLAOU

TVARIOS TIEKIMO GRANDINĖS IR JŲ POVEIKIS ĮMONĖS VEIKLOS REZULTATAMS

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Šiame tyrime nagrinėjami tvaraus tiekimo grandinės valdymo ir įmonių finansinių rezultatų ryšį, skiriant dėmesį aplinkosauginiam tvarumui, ESG veiklos rodikliams (aplinkos, socialinės ir valdysenos) ir šiltnamio efektą sukeliančių dujų (ŠESD) emisijoms. Tyrimas grindžiamas išteklių teorijos, gamtinių išteklių teorijos, suinteresuotųjų šalių teorijos ir institucinės teorijos principais, siekiant įvertinti, ar su tvarumu susiję įmonių gebėjimai yra susiję su geresniais finansiniais rezultatais įmonės lygmeniu. Tyrime taikoma kiekybinė metodologija. Analizuojami dešimties didelių tarptautinių įmonių, esančių Europoje ir Jungtinėse Amerikos Valstijose, duomenys 2016-2024 m. laikotarpiu. Naudojami „Bloomberg" terminalo duomenys: apskaitiniais rodikliais pagrįsti finansinės veiklos rodikliai (turto grąža, nuosavo kapitalo grąža ir veiklos pelningumo marža), bendrieji ESG įverčiai, atskiri ESG dimensijų rodikliai bei ŠESD sąnaudos pagal 1, 2 (vietos pagrindu) ir 3 apimtis. Duomenų analizei taikomi fixed-effects panel regressions modeliai su įmonių ir metų efektais. Tyrimo rezultatai - bendrieji ESG rodikliai ir dauguma ESG dimensijų yra teigiamai susiję su finansiniais rezultatais, tačiau šie ryšiai dažniausiai nėra statistiškai reikšmingi. Nustatyta, kad valdysenos dimensija turi statistiškai reikšmingas neigiamą ryšį su nuosavo kapitalo grąža, o tai leidžia teigti, jog su valdysena susiję atitikties reikalavimai ar investicijos gali lemti trumpalaikius kaštus. ŠESD sąnaudų analizė atskleidė, kad 2 apimties sąnaudos yra teigiamai ir statistiškai reikšmingai susijusios su finansiniais rezultatais, o 1 ir 3 apimčių poveikis nėra statistiškai reikšmingas. Apibendrinant - tvaraus tiekimo grandinės valdymo ir ESG poveikis finansiniams rodikliams yra priklausomas nuo konteksto ir dažniausiai pasireiškia per ilgesnį laikotarpį. Rezultatai nurodo, kad ESG rodiklių išskaidymo bei laiko dinamikos įtraukimas yra svarbu vertinant tvarumo ir veiklos rezultatų sąsajas.

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ABBREVIATIONS LIST

CSR – Corporate Social Responsibility

ESG - Environmental, Social, and Governance

EU – European Union

GHG - Greenhouse Gas

ISSB - International Sustainability Standards Board

NGO- Non-Governmental Organisations

NRBV - Natural Resource-Based View

OLS - Ordinary Least Squares

PLS-SEM - Partial Least Squares Structural Equation Modeling

ROA - Return on Assets

ROE - Return on Equity

SSCM - Sustainable Supply Chain Management

ŠESD - Šiltnamio efektą sukeliančios dujos

US - United States of America

VIF - Variance Inflation Factor

INTRODUCTION

Relevance. Sustainable supply chain management (SSCM) has become increasingly important as firms face regulatory pressures, investor scrutiny, and the need to address environmental and social impacts across supply chains. Recent studies highlight that SSCM influences firm performance through operational efficiency, risk reduction, and innovation (Bharti et al., 2025; Sharma et al., 2020; Zhu et al., 2018). Despite this, empirical evidence on the financial implications of SSCM remains mixed. Meta-analyses show generally positive links between environmental practices and corporate performance, but effects vary by firm size, industry, and geographic context (da Cunha et al., 2025; Geng et al., 2023; Govindan et al., 2020; Qorri et al., 2021). Other studies find that high Environmental, Social, and Governance (ESG) scores or sustainability efforts do not always translate into short-term accounting gains (Li et al., 2025; Sachin & Rajesh, 2022). Supply-chain-related environmental impacts, particularly Scope 3 greenhouse gas (GHG) emissions, represent the largest component of corporate carbon footprints and are often underexamined at the firm level due to data limitations (Bisceglia, 2024; Gill et al., 2024; Singh et al., 2023). Effective SSCM can reduce operational costs, enhance resilience, improve reputation, and support market access, yet these benefits frequently manifest over medium- to long-term horizons (Eccles et al., 2014; Golicic & Smith, 2013). Consequently, managers and investors face a pressing challenge: understanding which SSCM and ESG-related practices translate into measurable financial outcomes within planning horizons relevant for capital allocation. This study addresses this gap by examining the relationships between SSCM indicators, ESG pillars, disaggregated GHG emissions (Scope 1, Scope 2, Scope 3), and corporate financial performance in large multinational firms.

Novelty. Although the ESG-financial performance literature has grown rapidly, several gaps remain. Most studies rely on cross-sectional designs that emphasize breadth over depth, limiting insight into within-firm changes in sustainability practices (Truant et al., 2024). Scope 3 emissions, which often constitute the majority of a firm's supply-chain carbon footprint, are rarely integrated into firm-level econometric analyses due to data limitations (Bisceglia, 2024; Gill et al., 2024; Singh et al., 2023). This study contributes novelty in three ways. First, it adopts a firm-level longitudinal panel design (2016-2024), capturing within-firm variation and enabling the analysis of changes in SSCM practices and financial outcomes over time. Second, it disaggregates ESG performance into environmental, social, and governance pillars and analyzes Scope 1-3 GHG emissions separately, allowing differentiation between operational and upstream supply-chain impacts (Eccles et al., 2014; Gill et al., 2024). Third, the study is explicitly grounded in RBV, NRBV, and stakeholder-institutional theory, connecting internal capabilities with external

pressures to explain why SSCM investments may translate into financial performance. By combining pillar-level ESG and disaggregated GHG emissions in a fixed-effects panel framework, this research addresses limitations of aggregated ESG measures highlighted in prior studies (Friede et al., 2015; Truant et al., 2024) and provides more granular, mechanism-oriented insights into how SSCM affects corporate profitability. Following the classification of research novelty proposed by Kardelis (2017), this study contributes to the literature by investigating a less explored problem from a longitudinal perspective, applying established econometric methods to a new empirical context, and offering a disaggregated analysis of ESG and supply-chain emissions.

Subject matter. This thesis investigates whether observable SSCM indicators, operationalized as Bloomberg-reported overall ESG scores, disaggregated ESG pillar scores (environmental, social, governance), and reported GHG emissions (Scope 1, Scope 2 location-based, Scope 3), are systematically associated with firm financial performance, measured by ROA, ROE, and operating margin.

Problem statement. The central problem is that supply-chain sustainability investments are costly and often measured imprecisely, leaving managers without robust, firm-level evidence of whether such investments yield measurable accounting or market benefits within the planning horizons typically used for capital allocation decisions.

Aim. This study aims to empirically assess the relationship between supply-chain-related sustainability indicators and corporate financial performance in a purposive sample of large multinational firms operating in Europe and the United States over the 2016-2024 period.

Tasks. To achieve the stated aim, the study pursues the following tasks:

1. Analyze recent academic and practitioner literature on SSCM, ESG performance, and corporate financial outcomes, and formulate testable hypotheses;

2. Design an appropriate quantitative research methodology, including variable operationalization, panel-data structure, and econometric estimation strategy;

3. Compile, harmonize, and preprocess firm-level financial, ESG, and GHG emissions data from Bloomberg for the selected sample;

4. Estimate fixed-effects panel regression models assessing the relationship between SSCM indicators and financial performance while controlling for unobserved heterogeneity and time effects;

5. Evaluate model diagnostics and robustness checks to ensure the reliability and validity of empirical results;

6. Derive practical recommendations for managers and investors based on the empirical findings.

Research methods. The research strategy is quantitative and longitudinal, using firm-level panel data to examine the relationship between sustainability indicators and corporate financial performance. Data extraction and harmonization are performed using Bloomberg as the primary source for financial variables, ESG scores, ESG pillar indicators, and GHG emissions across Scopes 1, 2 (location-based), and 3. The empirical analysis is conducted in EViews. Panel least squares regressions with firm and year fixed effects are employed to control for unobserved, time-invariant firm heterogeneity and common time-specific shocks. This approach is appropriate given the small cross-sectional dimension and the focus on within-firm variation over time. The analysis proceeds in several stages. First, descriptive statistics are used to summarize the distribution and variation of financial performance measures, ESG indicators, and GHG emissions. Second, pairwise correlation analysis is conducted to explore preliminary relationships and assess potential multicollinearity among explanatory variables. Variance inflation factors (VIF) are computed for all multivariate models to formally evaluate multicollinearity. Third, baseline fixed-effects regression models are estimated to test the proposed hypotheses. Separate model specifications examine the effects of overall ESG performance, individual ESG pillar scores (environmental, social, governance), and disaggregated GHG emissions on return on assets (ROA), return on equity (ROE), and operating margin. Firm-level clustered robust standard errors are applied to account for within-firm dependence and heteroskedasticity. Finally, results are interpreted in light of the theoretical framework and existing empirical literature, and the extent to which the findings support the stated hypotheses is assessed. All variable definitions, transformations, and data limitations, including the unbalanced panel structure and differences in disclosure across firms and years, are documented to ensure transparency and replicability.

Practical value. This study provides practical value to corporate managers, supply-chain professionals, and investors facing increasing pressure to integrate sustainability considerations into strategic and operational decisions. As firms transition toward mandatory supply-chain sustainability reporting under frameworks such as the EU CSRD and International Sustainability Standards Board (ISSB) standards, uncertainty remains regarding the financial relevance of ESG indicators, particularly those related to upstream supply-chain emissions. By empirically examining the relationship between SSCM-related indicators: overall ESG scores, ESG pillar performance, and disaggregated GHG emissions (Scope 1, Scope 2, and Scope 3), and accounting-based performance measures (ROA, ROE, and operating margin), the study offers evidence-based insights into which sustainability metrics are more closely associated with short-

term financial outcomes. This supports managers in prioritizing sustainability initiatives under capital constraints and helps investors interpret ESG disclosures more critically in valuation and risk assessment. Overall, the study bridges sustainability reporting and financial decision-making by providing firm-level, data-driven evidence on how supply-chain sustainability indicators relate to commonly used profitability measures.

Structure of the paper. The thesis is organized as follows. Part 1 reviews theory and empirical evidence on SSCM and corporate performance, and derives the hypotheses tested empirically. Part 2 describes the data sources, sampling logic, variable construction, and the econometric approach, including diagnostics and robustness procedures. Part 3 presents the empirical results: descriptive statistics and main analysis, and interprets the statistical findings in light of observable corporate events and supply-chain disclosures, as well as stating the current study's limitations and implications. Additionally, all is concluded by summarizing principal findings, discussing managerial and policy implications, and offering recommendations for practitioners and avenues for future research.

1. Theoretical Part of Sustainable Supply Chain Management and Corporate Finance

SSCM has become a central topic in discussions of how firms (or corporates) can balance profitability with environmental and social responsibility. Seuring and Müller (2008) describe SSCM as a process that manages material, information, and financial flows across organizations while pursuing economic, environmental, and social objectives. This reflects the well-known "triple bottom line" perspective, which argues that long-term competitiveness is tied to performance in all three dimensions rather than financial outcomes alone. Similarly, Carter and Rogers (2008) emphasize that SSCM involves coordinated processes across companies that link operational efficiency and profitability with sustainability goals. Brandenburg et al. (2019) likewise define SSCM as the management of material, information, and capital flows, and cooperation among companies along the supply chain, while taking goals from all three dimensions of sustainable development into account. In practice, SSCM extends beyond forward logistics to include reverse and closed-loop processes (e.g., product take-back and recycling). Key aspects of SSCM include: triple bottom line (balancing financial, environmental, and social objectives) (Brandenburg et al., 2019); stakeholder engagement (addressing demands from customers, governments, Non-Governmental Organisations (NGOs), and other parties) (Li et al., 2025); resource efficiency (reducing waste and emissions through green design and operations, consistent with the NRBV) (Li et al., 2025); and collaboration and transparency (sharing information on sustainability such as carbon footprints among supply-chain partners). Truant et al. (2024) provide a systematic synthesis of ESG research in supply chains and underscore the central role of transparency, policy levers, and ESG-driven performance effects, findings that justify the focus on firm-level ESG scores and supply-chain emissions as measurable SSCM inputs (Truant et al., 2024).

1.1. Theoretical and Empirical Perspectives of Sustainable Supply Chain Management and Corporate Performance

Several theoretical perspectives should be seen as complementary rather than competing. The Resource-Based View (RBV) and Natural Resource-Based View (NRBV) focus on corporate-level resources and capabilities, explaining why some companies can transform sustainability investments into lasting competitive advantages, while stakeholder theory clarifies the incentives that drive corporates to develop these capabilities in the first place (Li et al., 2025; Park-Poaps & Rees, 2010). Institutional theory helps account for variation across contexts by showing how laws, norms, and market expectations shape the costs and benefits of adopting SSCM. Shibin et al. (2020) show, using Partial Least Squares Structural Equation Modeling (PLS-SEM) in the Indian

auto components sector, that coercive pressures and top-management engagement drive supply-chain connectivity and information sharing. These mechanisms plausibly link SSCM investments to environmental performance and, by extension, to firm financial metrics (Shibin et al., 2020). Taken together, these theories imply a causal chain: external pressures and stakeholder demands create incentives for firms to develop sustainability capabilities, which in turn determine whether SSCM leads to improved performance.

A tension remains between these perspectives. The RBV views capabilities as internally driven and relatively stable, whereas institutional and stakeholder theories emphasize the role of external pressures and shifting expectations. This raises important questions about timing and causality: do firms develop capabilities primarily because they have the resources to do so, or because they must respond to external demands? The literature is also ambiguous regarding the role of governance and disclosure practices in mediating these processes and regarding how quickly investments yield returns across different industries and firm sizes. These gaps are particularly salient for a study focused on Europe and the United States, where institutional pressures are significant and heterogeneous and where variations in governance practices may substantially influence outcomes.

This thesis adopts an integrated theoretical approach in which the RBV and NRBV serve as the primary lenses for explaining how sustainability-related capabilities could contribute to competitive advantage and financial performance. Stakeholder and institutional theories are treated as complementary frameworks that highlight the external pressures and contextual conditions under which firms develop and deploy these capabilities. This framing motivates the empirical focus on the relationship between sustainability performance indicators and financial outcomes, while acknowledging that governance structures, disclosure practices, and stakeholder pressures may shape these relationships in practice. Although these mechanisms are discussed as theoretically relevant, the empirical analysis concentrates on estimating direct associations between ESG-related measures and financial performance, given data availability and sample-size constraints.

Mechanisms linking SSCM to corporate performance are multifaceted. On a practical level, sustainable practices such as waste reduction, energy efficiency, and recycling can lower operational costs and improve financial margins over time (Golicic & Smith, 2013). Recent applied work shows that targeted engineering and IT-based efficiency upgrades can yield substantial reductions in energy use and emissions without compromising productivity, indicating that operational sustainability can deliver measurable environmental benefits at scale (Bharti et al., 2025). SSCM also strengthens resilience by reducing risks associated with regulation, resource

scarcity, and supply disruptions (Sharma et al., 2020; Zhang & Huang, 2024). At the same time, sustainability initiatives often drive innovation, particularly in eco-design and cleaner production processes, thereby improving quality and opening new markets (Carter & Easton, 2011). Firms with greener supply chains frequently gain reputational benefits that enhance customer loyalty and enable premium pricing (Zhu et al., 2018). Moreover, compliance with environmental and social standards is increasingly required to access specific markets, particularly in the European Union and North America. These combined effects suggest that SSCM can improve both financial and non-financial performance, though benefits often accrue over the long term rather than immediately.

Positive outcomes have been widely reported. For example, Eccles et al. (2014) show that integrating sustainability into corporate strategy improves operational efficiency and customer loyalty, leading to better financial results. Meta-analytic and review work also supports a generally positive sustainability-performance link (Alshehhi, 2024; Friede et al., 2015). Overall, many studies report cost savings, efficiency gains, and reputational benefits associated with SSCM (Alshehhi, 2024; Eccles et al., 2014; Friede et al., 2015).

Empirical research on SSCM's effect on corporate performance is rich but mixed. Several studies document positive links between SSCM and firm performance (Fu et al., 2022). In contrast, other evidence suggests benefits are not guaranteed: some empirical work found that high ESG or sustainability scores did not automatically translate into higher ROA or ROE (Sachin & Rajesh, 2022), and reviews note that "SSCM implementations are not always satisfactory" and firms may "fail to receive the desired returns" (Li et al., 2025). Meta-analyses of many studies report a positive overall relationship between environmental supply chain practices and corporate performance, while also highlighting substantial heterogeneity across contexts and practices (da Cunha et al., 2025; Geng et al., 2023; Govindan et al., 2020; Xin et al.,, 2025). Moderators such as firm size, industry sector, geographic region, and the specific sustainability practices adopted help explain why findings differ across studies (Holling & Backhaus, 2023; Qorri et al., 2021). Sánchez-Flores et al. (2020) demonstrate that SSCM research remains underdeveloped in emerging economies and that contextual factors critically affect how the three sustainability dimensions influence supply-chain performance. This reinforces the decision to account for institutional and regional heterogeneity when interpreting firm-level panel results (Sánchez-Flores et al., 2020). Other large-sample analyses indicate a mutually reinforcing relationship: stronger sustainability performance tends to accompany better financial performance, while financially stronger firms are more likely to invest in SSCM (Malik et al., 2025; Ortas et al., 2014). However, several studies, particularly in emerging markets, report little short-run improvement in

accounting-based returns following SSCM investment (Li et al., 2025; Sachin & Rajesh, 2022). In sum, the empirical literature suggests that while SSCM is increasingly seen as a driver of efficiency and competitiveness, its effect on financial outcomes varies and is often conditional on time horizon, firm characteristics, and institutional context (Geng et al., 2023; Govindan et al., 2020; Qorri et al., 2021).

1.2. ESG Pillars, Financial Outcomes, and Scopes 1-3

Corporate ESG performance is commonly divided into Environmental (E), Social (S), and Governance (G) components. Empirical studies frequently link higher overall ESG scores to better financial results (e.g., ROA, ROE) as well as non-financial benefits such as customer loyalty and brand value (Alshehhi, 2024; Pérez Estébanez & Sevillano Martín, 2025). Meta-reviews indicate that a majority of studies report a positive ESG-financial performance relationship, supporting hypotheses H1a-H1c: higher overall ESG should correlate with higher ROA, ROE, and operating margin.

The environmental pillar encompasses pollution control, resource efficiency, renewable energy, and carbon management. Effective environmental practices reduce operational costs, minimize waste, and lower regulatory risks, which can improve profitability. Evidence shows that firms with stronger environmental performance, including energy-efficient operations, low emissions, and green certifications, achieve higher productivity and medium-term financial gains, although initial investments may cause temporary lags before benefits appear (Gill et al., 2024; Pérez Estébanez & Sevillano Martín, 2025; Yin et al., 2025). In an SSCM context, environmental performance closely relates to supply-chain sustainability practices, particularly energy management, waste reduction, and Scope 1-3 emission controls.

The social pillar covers employee treatment, diversity, community engagement, and workplace safety. Positive social practices can enhance workforce productivity, strengthen brand reputation, and improve customer loyalty, indirectly supporting financial performance. Evidence suggests social aspects of Corporate Social Responsibility (CSR) are consistently associated with financial gains, especially in firms that actively engage stakeholders across the supply chain (Alshehhi, 2024; Pérez Estébanez & Sevillano Martín, 2025; Qiao et al., 2025).

Governance relates to board structure, transparency, shareholder rights, and ESG oversight. Strong governance can reduce agency costs, improve decision-making, and lower the cost of capital, potentially enhancing firm value. However, empirical effects on accounting-based profitability measures (ROA, ROE) are often weaker or more indirect compared to the environmental and social pillars (Al Amosh et al., 2022; Pérez Estébanez & Sevillano Martín,

2025). In SSCM terms, governance facilitates sustainability by supporting top-level commitment, ESG-linked incentives, and effective disclosure of supply-chain initiatives.

Operating margin reflects a firm's cost control and pricing power. Higher ESG performance, particularly environmental efficiency, can improve margins by reducing energy consumption, waste, and regulatory risks. Practitioner evidence shows that firms with strong ESG scores often achieve higher operating margins, although direct academic studies linking ESG to operating margin are more limited (Gill et al., 2024; Goeden, 2023). Within SSCM, operational improvements and supply-chain efficiencies serve as key channels translating ESG performance into profitability.

Across all pillars, ESG performance affects financial outcomes through operational and supply-chain mechanisms: environmental practices improve efficiency and reduce costs, social practices enhance human and relational capital, and governance ensures strategic alignment and accountability. These pathways align with the conceptual model, illustrating how sustainability efforts translate into ROA, ROE, and operating margin under varying stakeholder and institutional conditions.

GHG emissions are a central element of the environmental pillar. Scope 1 emissions are direct emissions from company-owned sources, Scope 2 are indirect emissions from purchased energy, and Scope 3 covers all other indirect emissions in the value chain, such as supplier operations, product use, and end-of-life disposal (Scope 1 and Scope 2 Inventory Guidance, 2025). Scope 3 typically dominates a company's carbon footprint, often accounting for 70-90% of total emissions, making supply-chain activities the primary driver of environmental impact (Gill et al., 2024). Singh et al. (2023) map the drivers, barriers, and practices for achieving a knowledge-based net-zero supply chain, highlighting the importance of multi-stakeholder action and policy support, which supports emphasis on Scope 3 exposure and the institutional context shaping SSCM outcomes (Singh et al., 2023).

High GHG emissions signal inefficiency, resource waste, and potential exposure to climate-related costs. Firms that actively engage suppliers to reduce Scope 3 emissions often realize productivity gains, risk mitigation, and potential cost savings, whereas firms that under-manage these emissions may incur hidden costs and investor concerns (Bisceglia, 2024; Gill et al., 2024; Zhao, 2025). Case evidence, such as in Scottish aquaculture, shows that Scope 3 often represents the majority of emissions, yet mitigation efforts typically focus on Scope 1/2, leaving the larger footprint unchecked (Bisceglia, 2024).

From a financial-performance perspective, negative relationships between emissions and firm outcomes (H3a-H3c) are expected. Heavy Scope 1/2 emissions imply high energy use or

outdated processes that erode margins, while high Scope 3 emissions indicate a carbon-intensive supply chain, potentially increasing regulatory, reputational, and operational risks. Therefore, lower emissions (Scope 3) should correspond to higher ROA, ROE, and operating margin, whereas high emissions are likely to depress these financial metrics (Bisceglia, 2024; Gill et al., 2024; Li et al., 2025).

Implementing SSCM involves managing the trade-offs inherent in the triple bottom line. Investments in sustainable processes can temporarily reduce profitability, even if they enhance competitiveness over the long term (Porter & van der Linde, 1995). Multi-tier supply chains add complexity and cost, and balancing stakeholder demands can be challenging when profitability goals conflict with social or environmental objectives (Li et al., 2025). Smaller firms often lack the resources to adopt advanced SSCM practices, leading to uneven adoption across industries. Additionally, some benefits of SSCM, such as enhanced reputation or reduced operational risk, may not be captured in traditional financial metrics. Several studies report short-term depressions in accounting returns following sustainability investments, with longer-term improvements occurring later (Crisóstomo et al., 2011; Delmas et al., 2012; Nelling & Webb, 2009; Pérez Estébanez & Sevillano Martín, 2025). Sectoral differences further influence outcomes (Hassan & Roychowdhury, 2021; Lima et al., 2024).

Corporate governance and transparency are critical for realizing SSCM's performance benefits. ESG-focused board committees, sustainability-linked executive incentives, and disclosure practices, such as sustainability reports and compliance with EU frameworks, build stakeholder trust and accountability (Almashhadani & Almashhadani, 2022; Gao et al., 2023). Stakeholder pressure from regulators, investors, and large customers often drives SSCM adoption, while Non-Governmental Organizations (NGOs) and media serve as influential secondary forces (Koberg & Longoni, 2019). Dai et al. (2021) find that institutional pressures and internal capabilities jointly determine SSCM adoption and that interactions (for example, between technical capabilities and customer/governance pressures) can produce counterintuitive effects. The evidence therefore motivates the inclusion of governance and pillar-level ESG measures alongside emissions in the empirical models (Dai et al., 2021). Firms that are transparent and responsive to these pressures are better positioned to convert SSCM investments into long-term operational and financial gains, supporting the hypothesized relationships between ESG performance, governance, and financial outcomes (H1c, H2c).

1.3. Key Findings and Conceptual Model for SSCM and Financial Performance

The literature presents a range of perspectives on the mechanisms and outcomes of SSCM implementation. Table 1 summarizes the key findings from selected studies, thus highlighting the diversity of contexts and conclusions.

Table 1

Summary of the Key Findings

Author	Finding
Almashhadani & Almashhadani (2022)	ESG-focused governance improves SSCM performance
Bharti et al. (2025)	Engineering upgrades, IT solutions, and supportive policy incentives can together reduce a pharmaceutical manufacturing site's CO_2 emissions by around 40% without lowering production or increasing costs
Carter & Rogers (2008)	SSCM links profitability with sustainability via RBV and stakeholder theory
Gao et al. (2023)	Sustainability disclosures improve stakeholder trust and market access
Geng et al. (2023)	Environmental practices generally improve financial performance, but effects vary
Golicic & Smith (2013)	Sustainable practices improve cost efficiency
Govindan et al. (2020)	Meta-analytic synthesis reporting a generally positive relationship between SSCM practices and corporate performance, while identifying industry and regional moderators
Holling & Backhaus (2023)	Large meta-analysis showing a positive overall relationship between green supply chain practices and corporate performance, while highlighting substantial heterogeneity across studies and moderators

Continuation of Table 1

Summary of the Key Findings

Kato & Manchidi (2025)	Systematic review in African manufacturing; propose framework with 6 drivers of SSCM; emphasize inclusive growth, institutional constraints
Li et al. (2025)	Upfront investments are costly and returns delayed
Ortas et al. (2014)	Financially strong firms invest more in SSCM, and SSCM improves performance
Qorri et al. (2021)	Meta-analysis that shows SSCM practices typically boost operational and economic outcomes but that effects depend on moderators like firm size, region and practice type
Sachin & Rajesh (2022)	SSCM does not improve ROA or ROE short-term
Seuring & Müller (2008)	SSCM integrates economic, environmental, and social goals
Sharma et al. (2020)	SSCM improves supply chain resilience
Zhu et al. (2018)	Greener supply chains improve reputation and market share

Source: compiled by the author based on research

As shown in Table 1, many studies find positive links between SSCM and corporate performance, but the evidence is not uniform. Differences in firm size, industry, geographic context, and type of sustainability practices lead to substantial variation in outcomes. Some research points to delayed returns or limited short-term improvements, particularly in emerging markets (Sachin & Rajesh, 2022; Li et al., 2025). These mixed results underscore the need for further empirical investigation into the mechanisms through which SSCM, ESG performance, and GHG emissions impact financial outcomes. This study aims to address this gap by examining the relationship between sustainable supply chain practices and firm-level profitability in a structured, quantitative framework.

This thesis proposes a conceptual framework linking SSCM and ESG factors to corporate financial performance. Drawing on the literature, the framework identifies key sustainability inputs, overall ESG performance, the three ESG pillars (environmental, social, and governance), and

Scope 1-3 GHG emissions, which together capture both internal practices and supply-chain-related environmental impacts.

SSCM-related ESG initiatives are expected to influence firm performance through multiple channels. Environmental practices, such as energy efficiency, waste reduction, and emissions management, can reduce operating costs. Social and governance practices may enhance workforce productivity, strengthen brand loyalty, and mitigate operational and regulatory risks. Supply-chain coordination and information sharing further reduce inventory risk and increase resilience. Consistent with the RBV, the NRBV, and stakeholder theory, these mechanisms translate sustainability inputs into improved operational performance, thereby supporting financial outcomes.

The strength of these relationships may vary with external conditions. Stakeholder pressure, industry norms, and regulatory environments can amplify or attenuate the benefits of SSCM and ESG practices. High demand from customers, regulators, or ESG-focused investors may strengthen the financial payoff from sustainability investments. While these moderating factors are theoretically relevant, the empirical analysis focuses on estimating direct associations between sustainability measures and financial performance, given data availability and sample-size constraints.

The framework identifies corporate financial performance measures (ROA, ROE, and operating margin) as the primary outcomes. Improvements in efficiency, innovation, and market positioning driven by SSCM are expected to raise these profitability indicators, whereas high emissions or weak governance may erode them.

This conceptual model provides a theory-driven structure for the empirical analysis and guides the formulation of hypotheses H1-H3 It reflects the broader literature's view that sustainable supply chains influence financial performance through multiple, interrelated pathways, rather than a single direct effect (Gill et al., 2024; Zhao, 2025). By clearly linking ESG inputs, operational mechanisms, and financial outcomes, the framework justifies the empirical focus and interprets potential variation in results across firms, industries, and regions. Figure 1 presents the conceptual model for SSCM and financial performance adopted in this study.

Figure 1

Conceptual Model for SSCM and Financial Performance
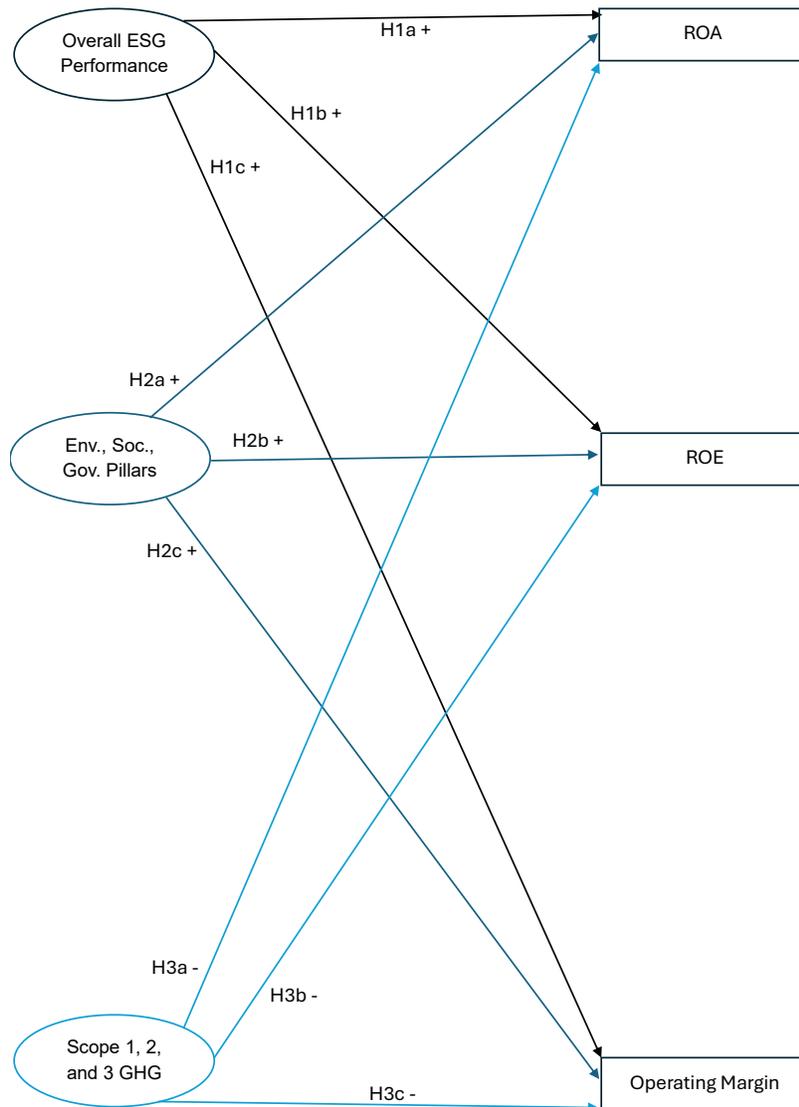
Source: compiled by the author based on research

Based on the conceptual framework, this study expects that firms' sustainability efforts, as captured by ESG performance and GHG emissions, influence financial outcomes through operational efficiencies, innovation, and stakeholder alignment.

Overall, Part 1 establishes SSCM as a multidimensional strategic construct that links environmental, social, and governance practices to corporate financial performance through internal capabilities and external pressures. Drawing on the RBV, NRBV, stakeholder theory, and institutional theory, the literature indicates that SSCM can enhance efficiency, resilience, and

competitiveness, while also responding to growing regulatory and stakeholder demands. However, prior empirical evidence on the financial effects of SSCM remains mixed, particularly for short-term accounting-based performance measures and supply-chain-related indicators such as Scope 3 GHG emissions. As identified in the research problem, it remains unclear which SSCM-related indicators (overall ESG performance, individual ESG pillars, or disaggregated GHG emissions) are most relevant for explaining firm-level financial outcomes within typical managerial planning horizons. Building on these theoretical insights and empirical gaps, Parts 2 and 3 develop and apply a quantitative panel-data methodology to test the proposed hypotheses and examine how sustainability-related supply-chain indicators relate to corporate profitability.

2. METHODOLOGICAL PART FOR ANALYZING THE IMPACT OF ESG PERFORMANCE AND SUPPLY CHAINS SUSTAINABILITY ON CORPORATE FINANCIAL PERFORMANCE

The second part of the study presents the methodological approach used to empirically investigate the relationship between supply chain sustainability indicators (overall ESG scores, ESG pillar performance, and Scope 1-3 GHG emissions) and corporate financial outcomes (ROE, ROA, Operational Margin). This section details the research aims and hypotheses, study design, variable definitions, estimation strategy, diagnostic tests, and limitations, thereby enhancing the transparency and reproducibility of the analysis.

2.1. Research Approach and Design

A quantitative research design was chosen because the study tests predefined hypotheses regarding the relationships between SSCM indicators and corporate financial outcomes, allowing objective measurement of statistical associations (Creswell & Creswell, 2018; Kumar, 2019). A longitudinal (panel) research design was chosen, tracking 10 multinational firms over the period 2016-2024. Panel data allows capturing both within-firm changes over time and controlling for time-invariant firm heterogeneity, providing a robust framework for testing the hypothesized relationships between sustainability practices and financial outcomes (Baltagi, 2021; Wooldridge, 2019). The objective of this methodological approach is to empirically assess how ESG performance, ESG pillars, and Scope 1-3 GHG emissions affect corporate financial performance (ROA, ROE, and operating margin) in large multinational firms. The empirical approach is grounded in RBV, NRBV, stakeholder, and institutional theory, thereby linking SSCM capabilities to potential competitive advantages while considering external pressures.

This study aims to examine the relationship between SSCM practices and corporate financial performance, with particular emphasis on environmental sustainability and ESG-related indicators.

H1a:

Firms with higher overall ESG performance are expected to be associated with higher ROA.

H1b:

Firms with higher overall ESG performance are expected to be associated with higher ROE.

H1c:

Firms with higher overall ESG performance are expected to be associated with higher operating margins.

H2a:

Higher ESG Pillars (Environmental, Social, Governance) performance is expected to be positively associated with firms' financial performance, measured by ROA

H2b:

Higher ESG Pillars (Environmental, Social, Governance) is expected to be positively associated with firms' financial performance, measured by ROE.

H2c:

Higher ESG Pillars (Environmental, Social, Governance) is expected to be positively associated with firms' financial performance, measured by operating margin.

H3a:

Higher Scope 1, 2 and 3 GHG emissions are expected to be negatively associated with firms' financial performance, measured by ROA

H3b:

Higher Scope 1, 2 and 3 GHG emissions are expected to be negatively associated with firms' financial performance, measured by ROE.

H3c:

Higher Scope 1, 2 and 3 GHG emissions are expected to be negatively associated with firms' financial performance, measured by operating margin.

All data for the study were obtained from the Bloomberg terminal under the supervisor's institutional subscription. The research adheres to ethical standards for responsible academic work and uses correct citation practices throughout. Data preprocessing steps, such as cleaning missing values and verifying variable definitions, were documented to ensure transparency and replicability. Bloomberg provided harmonized annual financials (ROA, ROE, Operational Margin), standardized ESG measures (aggregate ESG score and pillar scores for Environmental, Social, Governance), and GHG reporting fields (Scope 1, Scope 2 location-based, and Scope 3 GHG emissions). The sampling procedure consisted of firms: (1) having continuous Bloomberg coverage for the key variables for the majority of the 2016-2024 period, (2) operating large international supply chains, and (3) being distributed across the US and Europe to allow comparison across regulatory environments. The final sample includes 10 firms meeting these criteria.

Before importing into EViews, the dataset was organized in a long (stacked) panel format in Excel. Each row represented one firm-year observation and contained, at a minimum, the panel keys: firm id, company, and year. The file was saved in .xlsx format and designed for direct import

to an EViews panel workfile. Key cleaning steps performed in Excel before import: (1) performance ratios (ROA, ROE, Operating Margin) were entered as percentage values, and numeric formatting is consistent across years; (2) any missing data was left blank in the Excel cell; and (3) firm id was an integer unique per firm (e.g., 1 to 10), year used the calendar/fiscal year consistent with Bloomberg exports. The EViews software package was used for all estimations, diagnostics and robustness checks. The EViews workflow was as follows: (1) Balanced Panel workfile with cross-sections equal to the number of firms was created with the date range 2016-2024; (2) the cleaned Excel sheet was imported into the EViews workfile; and (3) in EViews Group view, Descriptive Statistics were run for mean, standard deviation, min, max for all variables which were followed by the main analysis.

Three financial performance indicators were used to capture different aspects of corporate performance: (i) ROA (net income divided by total assets, measuring operational efficiency, as per Equation 1); (ii) ROE (net income divided by shareholders' equity, capturing shareholder return, as per Equation 2); and (iii) Operating Margin (operating income divided by revenue, reflecting operational profitability independent of financing and taxes, as per Equation 3).

$$(1)\ \text{ROA} = \frac{\text{Net Income}}{\text{Total Assests}} \qquad (1)$$

$$(2)\ \text{ROE} = \frac{\text{NET Income}}{\text{Shareholders'Equity}} \qquad (2)$$

$$(3)\ \text{OM} = \frac{\text{Operating Income}}{\text{Revenue}} \qquad (3)$$

The independent variables were: (i) ESG Score (a composite indicator reflecting overall sustainability performance); (ii) Environmental, Social, Governance Pillars (disaggregated ESG components to evaluate dimension-specific effects); and (iii) GHG Scope Emissions (Scope 1 (direct emissions), Scope 2-location-based (energy-related emissions), Scope 3 (indirect emissions), capturing firms' environmental impacts at different supply chain levels).

Descriptive statistics (Equations 4 and 5) were calculated for all variables, including mean, standard deviation, minimum, and maximum values, as well as correlations (Equation 6). These preliminary analyses are essential for several reasons: they identify outliers that could bias regression results, assess the distribution and variability of variables, and check assumptions such as normality and homoscedasticity necessary for valid regression inference. This step ensures that the quantitative models are based on reliable and interpretable data.

$$(4) \; \bar{x} = \frac{1}{N}\Sigma_{i=1}^{N} x_i \tag{4}$$

where: $\bar{x}$ - sample mean, x_i - observed value of variable x for observation i, i - index of observation, N – total number of observations in the sample, $\Sigma_{i=1}^{N}$- summation operator indicating that the values of x_i are summed from the first to the N-th observation.

$$(5) \; SD = \sqrt{\frac{\Sigma_{i=1}^{N}(X_i-\bar{X})^2}{N-1}} \tag{5}$$

where: SD - sample standard deviation, X_i - observed value of variable, $\bar{X}$ – sample mean of variable X, i – index of observation, N – total number of observations in the sample, $\Sigma_{i=1}^{N}$- summation operator indicating that the values of x_i are summed from the first to the N-th observation, $(X_i - \bar{X})^2$ – squared deviation of observation i from the sample mean, N-1 - degrees of freedom used to obtain an unbiased estimator of the population variance.

$$(6) \; r_{XY} = \frac{\Sigma_{i=1}^{N}(X_i-\bar{X})(Y_i-\bar{Y})}{(N-1)SD_X SD_Y} \tag{6}$$

where: N is the number of observations, $\bar{X}$ and $\bar{Y}$ - sample means, SD_X and SD_y – standard deviation.

To investigate the relationships between sustainability practices and corporate performance, fixed-effects panel regressions were specified. This approach controls for unobserved time-invariant heterogeneity across firms and temporal shocks affecting all firms in a given year. As per Equation 7, the general model is:

$$(7) \; Y_{it} = \alpha + \beta_1 ESG_{it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{7}$$

where: Y_{it} - dependent financial performance variable for firm - i at time - t; β_1- estimated coefficient; μ_i - firm fixed effects; λ_t - year fixed effects; ε_{it} - error term.

To allow evaluations of overall sustainability effects and dimension-specific impacts, separate regressions were estimated for: ESG total impact on ROA, ROE, Operating Margin,

ESG pillars impact on ROA, ROE, Operating Margin, and GHG Scopes impact on ROA, ROE, Operating Margin. For a more specific model equation, see equation 8-10.

$$(8)\ Y_{it} = \alpha + \beta_1 ESGscore_{it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{8}$$

where: Y_{it} - dependent financial performance variable for firm - i at time - t; β_1- estimated coefficient; μ_i - firm fixed effects; λ_t - year fixed effects; ε_{it} - error term.

$$(9)\ Y_{it} = \alpha + \beta_1 Env_{it} + \beta_2 Soc_{it} + \beta_3 Gov_{it\,it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{9}$$

where: Y_{it} - dependent financial performance variable for firm - i at time - t; $\beta_{1,2,3}$- estimated coefficient; μ_i - firm fixed effects; λ_t - year fixed effects; ε_{it} - error term.

$$(10)\ Y_{it} = \alpha + \beta_1 Scope1_{it} + \beta_2 Scope2_{it} + \beta_3 Scope3_{it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{10}$$

where: Y_{it} - dependent financial performance variable for firm - i at time - t; $\beta_{1,2,3}$- estimated coefficient; μ_i - firm fixed effects; λ_t - year fixed effects; ε_{it} - error term.

To account for potential delayed effects of sustainability initiatives on financial performance and to reduce concerns about reverse causality, overall ESG score and Scope 3 GHG emissions were included with a one-year lag in additional fixed-effects models. Lagged variables were constructed such that the value of each sustainability indicator in year $t-1$ was used to explain financial outcomes in year t. This choice reflects the theoretical expectation that broad ESG performance and upstream supply-chain impacts (Scope 3) are more likely to influence profitability over time, whereas operationally focused indicators (e.g., ESG pillars, Scope 1 and 2 emissions) are expected to produce more immediate effects. The lagged models follow the same fixed-effects structure as the baseline specifications (Equations 8-10), including firm and year fixed effects. Statistical significance, coefficient magnitude, and model fit were compared between contemporaneous and lagged models to assess the robustness and temporal sensitivity of the estimated relationships. Limitations related to sample size and panel length constrained the ability to include additional lagged variables, which could be explored in future research.

In addition to regression-based analysis, selective graphical diagnostics were employed to support the interpretation of empirical results (Tufte & Graves-Morris, 1983.). Scatterplots were generated for key relationships that were either statistically significant or theoretically important

but statistically insignificant in the regression analysis (relationships between ESG scores and ROA, and between Scope 2 GHG emissions and operating margin). These visualizations were used to examine firm-level heterogeneity, potential scale effects, clustering, and non-linear patterns that parametric regression models may not fully capture. Scatterplots serve as a complementary tool to regression analysis, enhancing transparency and aiding the interpretation of complex sustainability and performance relationships without altering the underlying econometric results. Graphical trend analysis was conducted to provide visual context for the regression results and to explore the evolution of ESG performance, GHG emissions, and financial performance indicators over time. Line plots were used to examine firm-level and aggregate trends across the sample period, helping to identify temporal patterns, structural shifts, and potential outliers. These graphical analyses complement the econometric models by enhancing transparency and supporting interpretation, but they do not substitute for formal statistical inference.

All regressions were conducted in EViews (IHS Markit, 2021), with fixed effects enabled for both cross sections (firms) and periods (years). The fixed-effects estimator was chosen because it accounts for unobserved firm characteristics that could confound the relationships, such as firm culture or long-term strategy, consistent with best practices in panel data econometrics. Standard errors are robust to heteroskedasticity.

Multicollinearity among independent variables was assessed using VIFs (Equation 11) from pooled ordinary least squares (OLS) models, since VIFs are not directly available for panel fixed effects (Equation 12) (O'Brien, 2007). For all multi-regressor models (ESG pillars, GHG scopes), centered VIF values were below 5, indicating no serious multicollinearity concerns. For example, in the Model examining GHG emissions' impact on Operating Margin, centered VIFs for Scope 1, Scope 2, and Scope 3 were 1.44, 1.16, and 1.62, respectively. This suggests that coefficient estimates are reliable and not artificially inflated by collinearity.

$$(11)\ VIF = \frac{1}{1-R_j^2} \qquad\qquad (11)$$

where: VIF - variance inflation factor for explanatory variable, R_j^2 - coefficient of determination obtained from an auxiliary regression in which explanatory variable j is regressed on all other explanatory variables in the model, j - index of the explanatory variable being tested for multicollinearity.

$$(12) \; rxy = \frac{\sum_{i=1}^{n}(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i-\bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i-\bar{Y})^2}} \tag{12}$$

where: rxy - Pearson correlation coefficient measuring the strength and direction of the linear relationship between variables X and Y, x_i - observed value of variable X for observation i, Y_i - observed value of variable Y for observation i, $\bar{X}$ - arithmetic mean of variable X, $\bar{Y}$ - arithmetic mean of variable Y, i - index of observations, n - total number of observations in the sample, $\sum$ – summation operator, $(X_i - \bar{X})(Y_i - \bar{Y})$ - joint deviation of X and Y from their respective means, $\sum_{i=1}^{n}(X_i - \bar{X})^2$ - total squared deviation of variable X, $\sum_{i=1}^{n}(Y_i - \bar{Y})^2$ - total squared deviation of variable Y.

A pairwise correlation analysis confirmed that no pairs of explanatory variables exceeded the critical correlation thresholds. The highest correlation among regressors was .744, which falls below the commonly accepted threshold for multicollinearity. Although fixed effects control for unobserved heterogeneity, the models cannot fully rule out potential endogeneity due to reverse causality (e.g., profitable firms investing more in sustainability initiatives). Additionally, the relatively small sample (10 firms) may limit external generalizability. Future work could use longer time spans or larger samples to draw broader inferences.

This study follows a structured quantitative research design based on secondary panel data analysis. Firm-level panel data for 10 multinational companies over the period 2016-2024 were collected from Bloomberg and organized in a longitudinal format. The empirical analysis proceeds in stages. First, descriptive statistics and graphical analyses, including scatterplots and trend lines, were used to explore data distributions, temporal patterns, and firm-level heterogeneity. Second, pairwise correlation analysis and VIF were computed to assess potential multicollinearity among explanatory variables. Third, fixed-effects panel regressions with firm and year effects were estimated to test the hypothesized relationships between ESG performance, ESG pillars, GHG emissions, and financial performance indicators (ROA, ROE, and Operating Margin). To assess temporal robustness and reduce concerns about reverse causality, one-year lagged values of the overall ESG score and Scope 3 emissions were also included in additional regressions. Finally, heteroskedasticity-robust standard errors and multicollinearity checks were performed to ensure the reliability and validity of the results. These steps provide a transparent and reproducible framework for evaluating the financial implications of sustainable supply chain practices and accurately reflect the scope of the analyses conducted.

3. RESEARCH PART ANALYZING THE IMPACT OF ESG PERFORMANCE AND GHG EMISSIONS ON CORPORATE FINANCIAL PERFORMANCE

This part of the study presents the empirical analysis undertaken to address the research objectives and test the proposed hypotheses regarding the relationship between ESG performance, supply chain sustainability, and corporate financial outcomes. First, descriptive statistics are employed to provide an overview of the dataset, outlining key characteristics, distributions, and variations in ESG scores, ESG pillar indicators, GHG emissions, and financial performance measures. Next, preliminary analyses are used to assess high-level relationships between ESG-related indicators and financial performance metrics. After verifying the underlying econometric assumptions, this section reports the regression results for models examining the effects of overall ESG performance, individual ESG pillars, and Scope 1-3 GHG emissions on ROA, ROE, and operating margin. To account for potential delayed effects of sustainability initiatives on financial performance and to mitigate concerns regarding reverse causality, additional fixed-effects models were estimated using one-year lagged values of ESG score and GHG Scope 3 variables. These lagged models follow the same fixed-effects structure as the baseline specifications, allowing an assessment of whether past sustainability performance influences current profitability. The findings are then interpreted within the theoretical framework and existing literature, thereby highlighting which sustainability dimensions appear most relevant to financial performance. Finally, the results are synthesized to assess the extent to which the empirical evidence supports the stated hypotheses.

3.1. Descriptive Statistics

Table 2 presents the descriptive statistics for all variables used in the analysis for the period 2016-2024. The sample includes 10 companies over nine years (82-80 observations depending on the model). ROA, ROE, and Operating Margin capture financial performance, while ESG scores, their Environmental, Social, and Governance pillars, and GHG emissions (Scopes 1, 2, and 3-Location based) serve as independent variables.

Table 2

Descriptive Statistics of 10 Companies

Variable	Mean	Std. Dev	Min	Max	N
ROA	7.876	5.992	-.062	28.36	73
ROE	29.342	32.639	-1.91	175.46	73
Operating Margin	13.849	9.03	1.82	30.29	73
ESG Score	4.767	.895	2.96	6.55	73
Env. Pillar	4.963	1.563	2.55	8.68	73
Soc. Pillar	3.107	1.178	1.23	6.3	73
Gov. Pillar	7.375	.943	4.72	8.55	73
GHG Scope 1	2654.468	2911.227	34.4	14270	73
GHG Scope 2 (Location Based)	3772.284	3950.981	575.5	15670	73
GHG Scope 3	152426.9	164311.8	471.2	625301	73

Note. The Environmental Pillar in the table is called Env. Pillar. The Social Pillar in the table is called Soc. Pillar. The Governance Pillar in the table is called Gov. Pillar

Source: compiled by the author based on research

Table 2 reveals substantial heterogeneity among firms, particularly with respect to ESG scores and GHG emissions across Scopes 1, 2, and 3, reflecting differences in firm size, operational complexity, industry characteristics, and sustainability strategies. Governance scores exhibit higher average values and lower dispersion relative to Environmental and Social pillars, suggesting uneven performance across ESG dimensions. Financial performance indicators also display considerable variation, especially for ROE, indicating differences in profitability and capital structure across firms. The large ranges observed in emissions and financial ratios suggest skewed distributions and potential outliers, which is typical for firm-level panel data. Although the panel covers a fixed set of firms over the sample period, the number of observations reflects an unbalanced structure due to differences in sustainability disclosure and data availability across firms and years.

The box plot analysis provides an overview of the distributional properties of financial performance indicators, ESG-related measures, and GHG emissions over the 2016-2024 period. For financial performance, ROA and operating margin exhibit relatively stable distributions over time, with modest increases in median values and limited dispersion, indicating broadly consistent profitability across firms. ROE shows greater variability, particularly around the 2020-2022 period, with wider interquartile ranges and higher upper values, reflecting increased heterogeneity in equity returns during this timeframe. Regarding ESG measures, the overall ESG score and its individual pillars display a clear upward shift in their distributions over time. Medians for the Environmental, Social, and Governance pillars steadily increase, while interquartile ranges remain relatively contained, suggesting gradual and broadly shared improvements in sustainability performance across firms rather than changes driven by a small subset of companies. The Governance pillar shows slightly higher central values than the Environmental and Social pillars, indicating stronger or earlier development of governance-related practices. For GHG emissions, Scope 1 and Scope 2 emissions exhibit moderate dispersion, with relatively stable median levels across years, although the distributions widen in later periods, consistent with increasing heterogeneity in firms' emissions intensity and reporting practices. In contrast, GHG Scope 3 emissions exhibit substantially larger dispersion and higher variability throughout the sample period, with both the median and upper ranges increasing over time. This reflects the complexity, firm-size sensitivity, and evolving disclosure practices associated with value-chain emissions. Overall, the box plots suggest that while ESG scores and financial performance measures show gradual improvements with relatively contained dispersion, emissions (particularly Scope 3) are characterized by pronounced heterogeneity across firms and over time. These patterns underscore the importance of using robust econometric techniques when assessing the relationship between SSCM-related indicators and corporate financial performance.

Overall, the descriptive statistics and boxplot analyses reveal clear patterns alongside substantial heterogeneity across firms and over time. Financial performance indicators exhibit moderate dispersion, with ROE showing greater variability than ROA and operating margin, reflecting differences in profitability and capital structure. ESG scores and their Environmental, Social, and Governance pillars display a gradual upward trend with relatively stable distributions, suggesting broadly shared improvements in sustainability performance rather than changes driven by a small subset of firms. In contrast, GHG emissions (particularly Scope 3) are characterized by pronounced dispersion and increasing variability, underscoring the complexity of emissions measurement and firm-level differences in operational scale and disclosure

practices. The presence of skewed distributions and an unbalanced panel structure is consistent with firm-level ESG and emissions data and motivates the use of robust econometric techniques. Taken together, these findings indicate sufficient variation across SSCM-related indicators and financial performance measures to justify further empirical investigation, providing a foundation for the subsequent correlation analysis that explores the direction and strength of associations between sustainability performance and corporate financial outcomes.

3.2. Correlation Analysis (Multicollinearity Check)

Before running multi-regressor models, pairwise correlations were examined to assess potential multicollinearity among the explanatory variables (Table 3).

Table 3

Correlation Matrix of Independent Variables

	Soc. Pillar	ROE	ROA	Operating Margin	Gov. Pillar	GHG Scope 3	GHG Scope 2 (Location Based)	GHG Scope 1	Env. Pillar	ESG Score
Soc. Pillar	1	0.152998	0.092216	-0.11245	-0.34654	0.251077	-0.18107	-0.0421	0.499325	0.744426
ROE	0.152998	1	0.922078	0.661653	0.262322	-0.31604	-0.26877	-0.3416	0.063	0.234864
ROA	0.092216	0.922078	1	0.777497	0.411544	-0.34115	-0.28072	-0.3450	0.015196	0.226882
Operating Margin	-0.11245	0.661653	0.777497	1	0.326666	-0.29888	-0.43965	-0.4936	0.026982	0.233337
Gov. Pillar	-0.34654	0.262322	0.411544	0.326666	1	-0.40598	0.109316	-0.0047	-0.295	-0.17386
GHG Scope 3	0.251077	-0.31604	-0.34115	-0.29888	-0.40598	1	0.136312	0.25377	-0.42827	0.111978
GHG Scope 2 (Location Based)	-0.18107	-0.26877	-0.28072	-0.43965	0.109316	0.136312	1	0.89468	-0.35005	-0.53211
GHG Scope 1	-0.04211	-0.34161	-0.34503	-0.49358	-0.00473	0.253772	0.894677	1	-0.35005	-0.39221
Env. Pillar	0.499325	0.063	0.015196	0.026982	-0.295	-0.42827	-0.35005	-0.3501	1	0.855148
ESG Score	0.744426	0.234864	0.226882	0.233337	-0.17386	0.111978	-0.53211	-0.3922	0.855148	1

Note. The Environmental Pillar in the table is called Env. Pillar. The Social Pillar in the table is called Soc. Pillar. The Governance Pillar in the table is called Gov.

Source: compiled by the author based on research

Table 3 reports the pairwise correlation matrix for the variables included in the empirical analysis. Several variables display moderate correlations, particularly among accounting-based measures of financial performance and among GHG emissions across different scopes, reflecting their underlying conceptual and operational relatedness. For example, the ESG score is positively correlated with the environmental pillar score, while GHG emissions (Scope 1, Scope 2, and Scope 3) are positively correlated with one another. Importantly, with the exception of these conceptually related variables, none of the pairwise correlations among the explanatory variables included simultaneously in the regression models exceed commonly used thresholds (approximately 0.8-0.9) that would indicate severe multicollinearity. To mitigate potential redundancy, highly correlated variables were not included concurrently in the same model specifications but were instead introduced in alternative regression variants where appropriate. Overall, the correlation structure suggests that multicollinearity is unlikely to materially bias the estimated coefficients. Nevertheless, VIFs were computed in the regression analysis to provide a formal diagnostic of multicollinearity for all multivariate models (Model 2, Model 2b, Model 2c, Model 3, Model 3b, Model 3c). Across all specifications, VIF values ranged between 1.0 and 1.6, well below conventional thresholds, indicating no multicollinearity concerns. Detailed VIF results are reported in Annex A.

3.3. Regression Results

Hypotheses are tested across three sets of models: (i) overall ESG performance (H1a-H1c), (ii) ESG pillar effects (H2a-H2c), and (iii) GHG emissions (H3a-H3c), corresponding to different firm financial performance measures. Fixed-effects panel regressions are employed throughout to control for unobserved, time-invariant firm-specific characteristics and common year effects that may jointly influence ESG-related variables and financial outcomes.

Model 1 examines the relationship between overall ESG performance and ROA over the period 2016-2024. The model is estimated using fixed-effects panel regression with firm and year fixed effects. Table 4 reports the results.

Table 4

Model 1 Fixed-Effects Panel Regression Results

Dependent Variable	ROA			
Method	Panel Least Squares			
Sample Period	2016-2024			
Cross-sections	10			
Total Observations	82			
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant (C)	1.419	3.794	0.374	0.710
ESG_SCORE	1.334	0.811	1.645	0.105
R-squared	.803			
Adjusted R-squared	.746			
S.E. of regression	2.893			
F-statistic	14.239			
Prob(F-statistic)	0			
Durbin-Watson	1.439			

Source: compiled by the author based on research

The ESG score exhibits a positive coefficient (β = 1.334) but is not statistically significant (p = 0.105). Accordingly, there is insufficient evidence to reject the null hypothesis of no relationship between ESG performance and ROA. Hypothesis H1a is not supported. The model explains approximately 80% of the variation in ROA (R^2 = 0.803). This relatively high explanatory power is largely attributable to the inclusion of firm and year fixed effects, which capture persistent differences across firms as well as common macroeconomic and industry-wide shocks over time. Overall, while the direction of the estimated ESG effect is consistent with theoretical expectations, the lack of statistical significance suggests that ESG performance does not exert a robust impact on ROA within the sample period considered. VIFs computed for the model indicate no evidence of severe multicollinearity among the included regressors, supporting the reliability of the estimated coefficients.

Model 1b examines the relationship between overall ESG performance and ROE over the period 2016-2024. Firm and year fixed effects are included. Table 5 presents the results.

Table 5

Model 1b Fixed-Effects Panel Regression Results

Dependent Variable	ROE			
Sample Period	2016-2024			
Total Observations	82			
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant (C)	-2.870	26.726	-0.107	0.915
ESG_SCORE	6.739	5.713	1.180	0.243
R-squared	0.663			
Adjusted R-squared	0.567			
S.E. of regression	20.380			
F-statistic	6.900			
Prob(F-statistic)	0			
Durbin-Watson	0.560			

Source: compiled by the author based on research

The ESG score coefficient is positive ($\beta = 6.739$) but not statistically significant ($p = 0.243$). Thus, no statistically significant relationship between ESG performance and ROE is observed. Hypothesis H1b is not supported. The model explains approximately 57% of the variation in ROE. As in Model 1, the explanatory power largely reflects the inclusion of firm and year fixed effects, which account for persistent firm-level differences and common time effects. VIFs for the model remain below conventional thresholds, suggesting that multicollinearity does not materially affect the estimated coefficients. Overall, while the direction of the ESG coefficient is consistent with theoretical expectations, the absence of statistical significance suggests that ESG performance does not exert a robust effect on ROE within the sample period examined. Taken together, the results from Models 1 and 1b indicate that overall ESG performance does not exhibit a statistically significant relationship with accounting-based measures of firm profitability once firm and year fixed effects are accounted for.

Model 1c examines the relationship between ESG performance and Operating Margin over the period 2016-2024 using firm and year fixed effects. Table 6 reports the results.

Table 6

Model 1c Fixed-Effects Panel Regression Result

Dependent Variable	OPERATING_MARGIN			
Sample Period	2016–2024			
Total Observations	82			
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant (C)	8.272	3.120	2.651	0.010
ESG_SCORE	1.024	0.667	1.536	0.130
R-squared	0.945			
Adjusted R-squared	0.929			
S.E. of regression	2.379			
F-statistic	59.745			
Prob(F-statistic)	0			
Durbin-Watson	1.917			

Source: compiled by the author based on research

The ESG score has a positive coefficient (β = 1.024) but is not statistically significant (p = 0.130). Therefore, the results do not provide empirical support for a relationship between ESG performance and operating margin. Hypothesis H1c is not supported. The model explains approximately 93% of the variation in operating margin. As with the preceding models, the high explanatory power largely reflects the inclusion of firm and year fixed effects, which capture persistent firm-level characteristics and common temporal effects. Diagnostic checks, including VIFs, indicate no evidence of severe multicollinearity affecting the regression estimates. Overall, while the estimated coefficient aligns with theoretical expectations regarding the potential profitability benefits of strong ESG performance, the absence of statistical significance suggests that such effects are not robust within the sample period examined. Across Models 1, 1b, and 1c, overall ESG performance exhibits consistently positive but statistically insignificant coefficients across all three accounting-based measures of financial performance. Collectively, these findings suggest that while ESG performance may be directionally associated with improved profitability, it does not exert a statistically robust effect on ROA, ROE, or operating margin once firm and year fixed effects are taken into account. Accordingly, Hypotheses H1a, H1b, and H1c are not supported.

Although the coefficients on the overall ESG score are positive across all three models, the absence of statistical significance suggests that improvements in aggregate ESG performance do not translate into short-term accounting benefits within the observed sample. This pattern is consistent with the descriptive analysis, where several firms exhibit steadily improving ESG scores alongside stable or even rising emissions and only modest changes in profitability. In particular, firms with extensive global supply chains and strong disclosure practices appear to achieve higher ESG ratings without immediate efficiency gains, indicating that ESG improvements may primarily reflect enhanced reporting, compliance, or governance processes rather than operational cost reductions. This finding supports the view that ESG-related investments may generate long-term strategic or reputational benefits rather than short-term financial returns, especially in large multinational firms.

Model 2 examines the relationship between ESG pillar scores and ROA over the period 2016-2024. Table 7 presents the fixed-effects regression results.

Table 7

Model 2 Fixed-Effects Panel Regression Result

Dependent Variable	ROA			
Sample Period	2016–2024			
Total Observations	82			
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant (C)	7.908	7.408	1.068	0.290
ENVIRONMENTAL_PILLAR_SCORE	0.865	0.476	1.819	0.074
SOCIAL_PILLAR_SCORE	0.323	0.587	0.550	0.584
GOVERNANCE_PILLAR_SCORE	-0.741	0.933	-0.794	0.430
R-squared	0.810656			
Adjusted R-squared	0.748576			
S.E. of regression	2.87997			
F-statistic	13.05824			
Prob(F-statistic)	0			
Durbin-Watson	1.500021			

Source: compiled by the author based on research

The Environmental Pillar exhibits a positive coefficient (β = 0.865) but is not statistically significant (p = 0.074). The Social Pillar coefficient is positive (β = 0.323) and not statistically significant (p = 0.584). The Governance Pillar coefficient is negative (β = -0.741) and not statistically significant (p = 0.430). None of the ESG pillar variables show a statistically significant relationship with ROA. Hypotheses H2a are not supported. The model explains approximately 75% of the variation in ROA, largely reflecting the inclusion of firm and year fixed effects.

Model 2b examines the relationship between ESG pillar scores and ROE using firm and year fixed effects. Table 8 reports the results.

Table 8

Model 2b Fixed-Effects Panel Regression Result

Dependent Variable	ROE			
Sample Period	2016–2024			
Total Observations	82			
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant (C)	101.590	50.473	2.013	0.049
ENVIRONMENTAL_PILLAR_SCORE	3.989	3.240	1.231	0.223
SOCIAL_PILLAR_SCORE	3.403	3.997	.0851	0.398
GOVERNANCE_PILLAR_SCORE	-14.063	6.359	-2.211	0.031
R-squared	0.698			
Adjusted R-squared	0.599			
S.E. of regression	19.622			
F-statistic	7.047			
Prob(F-statistic)	0			
Durbin-Watson	0.752			

Source: compiled by the author based on research

The Environmental and Social Pillar coefficients are positive but not statistically significant (p = 0.223 and p = 0.398, respectively). The Governance Pillar coefficient is negative and statistically significant (β = -14.063, p = 0.031). Thus, only the Governance Pillar shows a

statistically significant relationship with ROE. Hypothesis H2b is not supported. The model explains approximately 60% of the variation in ROE.

Model 2c examines the relationship between ESG pillar scores and operating margin over the period 2016-2024. Table 9 presents the results.

Table 9

Model 2c Fixed-Effects Panel Regression Result

Dependent Variable	OPERATING_MARGIN			
Sample Period	2016–2024			
Total Observations	82			

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant (C)	3.040	6.180	0.492	0.625
ENVIRONMENTAL _PILLAR_SCORE	0.189	0.397	0.477	0.635
SOCIAL_PILLAR_ SCORE	0.473	0.489	0.968	0.337
GOVERNANCE_ PILLAR_SCORE	1.048	0.779	1.346	0.183

R-squared	0.945			
Adjusted R-squared	0.927			
S.E. of regression	2.402			
F-statistic	52.771			
Prob(F-statistic)	0			
Durbin-Watson	1.937			

Source: compiled by the author based on research

All ESG pillar coefficients are positive but not statistically significant. Accordingly, no statistically significant relationship between ESG pillar scores and operating margin is observed. Thus, hypothesis H2c is not supported. The model explains approximately 93% of the variation in operating margin, largely due to the inclusion of firm and year fixed effects. Across Models 2, 2b, and 2c, ESG pillar scores generally exhibit coefficients consistent with theoretical expectations, but with limited statistical significance. Only the Governance Pillar shows a significant negative relationship with ROE, while the Environmental and Social Pillars do not demonstrate robust associations with ROA, ROE, or operating margin. Overall, these results suggest that ESG pillar dimensions do not have a consistently measurable impact on firm financial performance within the sample period.

The disaggregated pillar analysis provides additional insight into the mechanisms underlying the aggregate ESG results. While Environmental and Social pillar scores display positive but insignificant coefficients across most specifications, the Governance pillar exhibits a statistically significant negative association with ROE. This result may reflect short-term cost effects associated with governance reforms, such as board restructuring, enhanced compliance systems, or increased oversight, which can temporarily reduce shareholder returns. Descriptive trends indicate that several firms with already high governance scores experienced only incremental improvements over time, suggesting diminishing marginal financial returns from further governance enhancements. Conversely, firms undergoing more substantial governance changes may incur transitional costs that negatively affect equity-based performance measures in the short run. These findings imply that governance improvements may strengthen long-term institutional resilience while exerting downward pressure on ROE in the short to medium term.

Model 3 examines the relationship between GHG emissions and ROA using firm and year fixed effects. Table 10 reports the results.

Table 10

Model 3 Fixed-Effects Panel Regression Result

Dependent Variable	ROA			
Sample Period	2016–2024			
Total Observations	80			
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant (C)	4.544	2.543	1.787	0.079
GHG_SCOPE_1	0.00040	0.00083	0.478	0.635
GHG_SCOPE_2_LOCATION_BASED	0.00089	0.00044	2.014	0.049
GHG_SCOPE_3	-4.3E-06	4.48E-06	-0.959	0.341
R-squared	0.843			
Adjusted R-squared	0.790			
S.E. of regression	2.817			
F-statistic	15.843			
Prob(F-statistic)	0			
Durbin-Watson	1.342			

Source: compiled by the author based on research

Scope 2 (location-based) emissions exhibit a positive and statistically significant coefficient (β = 0.000892, p = 0.049). Scope 1 and Scope 3 emissions are not statistically significant. Thus, only Scope 2 emissions are significantly associated with ROA. Hypothesis H3a is not supported. The model explains approximately 79% of the variation in ROA, reflecting the contribution of fixed effects in capturing persistent firm-level and temporal variation.

Model 3b examines the relationship between GHG emissions and ROE. Table 11 presents the results.

Table 11

Model 3b Fixed-Effects Panel Regression Result

Dependent Variable	ROE			
Sample Period	2016–2024			
Total Observations	80			
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant (C)	-8.484	18.400	-0.461	0.646
GHG_SCOPE_1	0.005	0.006	0.991	0.326
GHG_SCOPE_2_LOCATION_BASED	0.007	0.003	2.471	0.016
GHG_SCOPE_3	-2.8E-05	3.24E-05	-0.861	0.393
R-squared	0.739			
Adjusted R-squared	0.650			
S.E. of regression	20.386			
F-statistic	8.333			
Prob(F-statistic)	0			
Durbin-Watson	0.598			

Source: compiled by the author based on research

Scope 2 emissions show a positive and statistically significant relationship with ROE (β = 0.0079, p = 0.016). Scope 1 and Scope 3 emissions are not statistically significant. Therefore, hypothesis H3b is not supported. The model explains approximately 65% of the variation in ROE.

Model 3c examines the relationship between GHG emissions and operating margin using firm and year fixed effects. Table 12 reports the results.

Table 12

Model 3c Fixed-Effects Panel Regression Result

Dependent Variable	OPERATING_MARGIN			
Sample Period	2016–2024			
Total Observations	80			
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant (C)	11.102	2.230548	4.977146	0
GHG_SCOPE_1	-0.00043	0.000725	-0.59316	0.5553
GHG_SCOPE_2_LOCATION_BASED	0.000956	0.000389	2.460351	0.0168
GHG_SCOPE_3	4.94E-06	3.93E-06	1.257537	0.2135
R-squared	0.94344			
Adjusted R-squared	0.924267			
S.E. of regression	2.471197			
F-statistic	49.20708			
Prob(F-statistic)	0			
Durbin-Watson	1.851959			

Source: compiled by the author based on research

Scope 2 emissions exhibit a positive and statistically significant coefficient (β = 0.000956, p = 0.017), while Scope 1 and Scope 3 emissions are not statistically significant. Thus, hypothesis H3c is not supported. The model explains approximately 92% of the variation in operating margin. Across Models 3, 3b, and 3c, Scope 2 (location-based) emissions consistently exhibit positive and statistically significant associations with ROA, ROE, and operating margin, whereas Scope 1 and Scope 3 emissions do not show statistically robust relationships. These findings suggest that only Scope 2 emissions are meaningfully related to firm financial performance within the sample period, and the broader hypotheses regarding GHG emissions (H3a-H3c) are not fully supported.

The emissions-based models reveal a differentiated relationship across emission scopes. Scope 2 (location-based) emissions exhibit a positive and statistically significant association with all three financial performance measures, whereas Scope 1 and Scope 3 emissions do not. This pattern may reflect the fact that Scope 2 emissions are more directly linked to energy consumption and efficiency, areas where firms can implement cost-saving measures through renewable energy sourcing or energy efficiency investments. Descriptive analysis shows that several firms achieved

notable reductions in Scope 2 emissions over time, coinciding with stable or improving profitability, suggesting that energy-related sustainability initiatives may yield measurable financial benefits. In contrast, Scope 3 emissions, which are heavily influenced by supplier behavior, logistics, and downstream activities, display high volatility and limited short-term financial linkage. This supports the argument that value-chain emissions management is structurally complex and less likely to generate immediate financial returns.

Taken together, the regression results suggest that sustainability-related financial effects are highly scope- and dimension-specific. Aggregate ESG scores and most pillar indicators do not exhibit robust short-term relationships with profitability, while specific operational sustainability factors, such as Scope 2 emissions, demonstrate clearer financial relevance. Firms characterized by extensive logistics networks and high upstream purchasing volumes display rising Scope 3 emissions despite improvements in ESG ratings, illustrating the disconnect between disclosure-based sustainability metrics and underlying supply-chain environmental impacts. These findings are consistent with the descriptive evidence, which highlights a divergence between improving ESG scores and rising value-chain emissions among several firms. The results imply that while ESG frameworks capture important aspects of corporate sustainability posture, they may not fully reflect the operational realities that drive short-term financial performance. This reinforces the importance of complementing ESG score-based measures with disaggregated emissions data when evaluating the financial implications of SSCM.

To examine whether sustainability practices exert delayed financial effects and to mitigate concerns of reverse causality, one-year lagged fixed-effects models were estimated. Lagged ESG score shows a positive but statistically insignificant association with ROA, ROE, and operating margin, consistent with prior findings that improvements in ESG performance may require more than one year to affect accounting outcomes. Similarly, lagged Scope 3 emissions coefficients are negative but not significant, indicating that upstream supply-chain environmental impacts are complex and may influence profitability over longer horizons. The inclusion of lagged variables does not materially alter the overall patterns observed in the baseline models, reinforcing the robustness of the results and highlighting the time-sensitive nature of SSCM investments. These findings are consistent with prior research suggesting that the financial benefits of ESG and SSCM initiatives often accrue over time rather than immediately (Golicic & Smith, 2013; Li et al., 2025; Wu et al., 2025). Table 13 and 14 show the lagged results below.

Table 13

Fixed-Effects Panel Regression Results: One-Year Lagged ESG Performance and Financial Performance

Dependent variable	ROA	ROE	Operational Margin
ESG score (t−1)	0.893	4.600	0.289
Prob	0.300	0.437	0.697
Constant	3.921	9.781	12.205
Prob	0.329	0.723	0.001
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	80	80	80
Number of firms	10	10	10
R^2 (within)	0.809	0.716	0.934
Adjusted R^2	0.756	0.638	0.916
F-statistic	15.436	9.190	51.608
Prob (F-statistic)	0.000	0.000	0.000

Source: compiled by the author based on research

Table 14

Fixed-Effects Panel Regression Results: One-Year Lagged Scope 3 Emissions and Financial Performance

Dependent variable	ROA	ROE	Operational Margin
Scope 3 emissions (t−1)	-4.09E-06	-2.78E-05	-4.85E-08
Prob	0.308	0.313	0.989
Constant	8.744	35.441	13.803
Prob	0.000	0.000	0.000
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	78	78	78
Number of firms	10	10	10
R² (within)	0.808	0.720	0.932
Adjusted R²	0.754	0.640	0.913
F-statistic	14.858	9.050	48.721
Prob (F-statistic)	0.000	0.000	0.000

Source: compiled by the author based on research

Overall, the inclusion of one-year lagged sustainability indicators confirms the primary results from the baseline models. Lagged ESG score coefficients remain positive but statistically insignificant across ROA, ROE, and operating margin, indicating that even past ESG improvements may not yield short-term accounting gains. Lagged Scope 3 emissions coefficients remain negative but insignificant, emphasizing the operational complexity and delayed impact of upstream supply-chain sustainability initiatives. Together, these results reinforce the interpretation that SSCM and ESG initiatives function primarily as strategic, long-term capabilities rather than immediate profit drivers. From a managerial perspective, the findings suggest that sustained ESG investments and ongoing supply-chain improvements are necessary to realize financial benefits, while short-term accounting metrics may not fully capture the value of these initiatives.

3.4. Supplementary Visual Analysis

To provide visual context for the regression results and illustrate underlying data patterns, graphical trend analysis was conducted to examine the evolution of SSCM-related ESG performance across firms over time (see Figure 2).

Figure 2

ESG Scores per Company 2016-2024
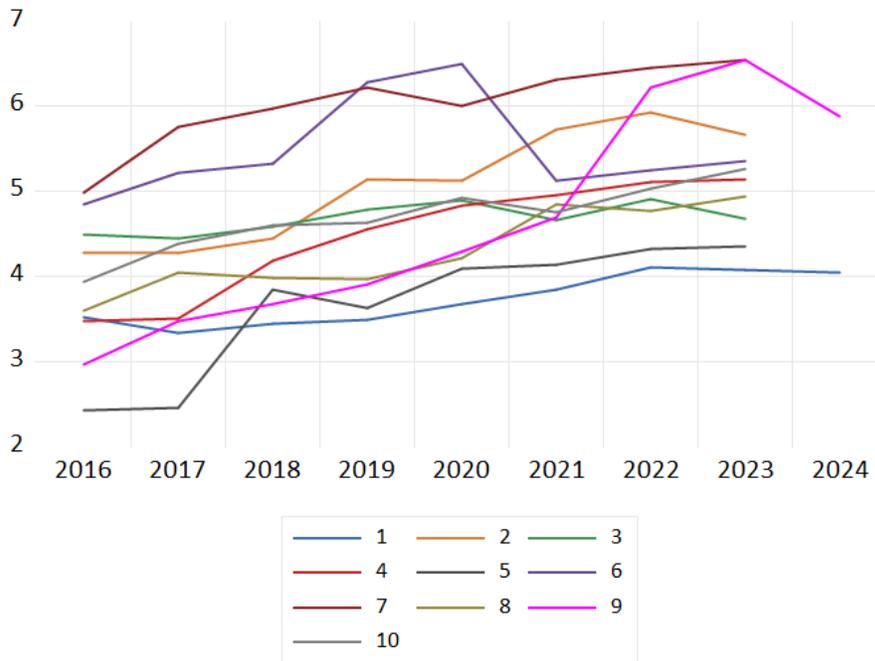

Note. 1-10 are companies analyzed

Source: compiled by the author based on research

Figure 2 illustrates ESG score trajectories for the ten companies over the 2016-2024 period. Overall, most firms exhibit an upward trend in ESG scores, suggesting gradual improvements in sustainability performance over time. However, heterogeneity across firms is evident. In particular, Company 6 experienced a noticeable decline around 2020-2021, which coincides with the COVID-19 pandemic period, although no causal inference is drawn at this stage. It should be noted that only two companies reported ESG scores for 2024, which may partially explain the apparent decline or increased volatility observed in the final year. This limitation highlights the unbalanced nature of the panel and underscores the need for caution when interpreting recent-year trends. Figure 3 presents the combined average ESG score across

all ten companies, providing a broader view of overall sustainability performance dynamics within the sample.
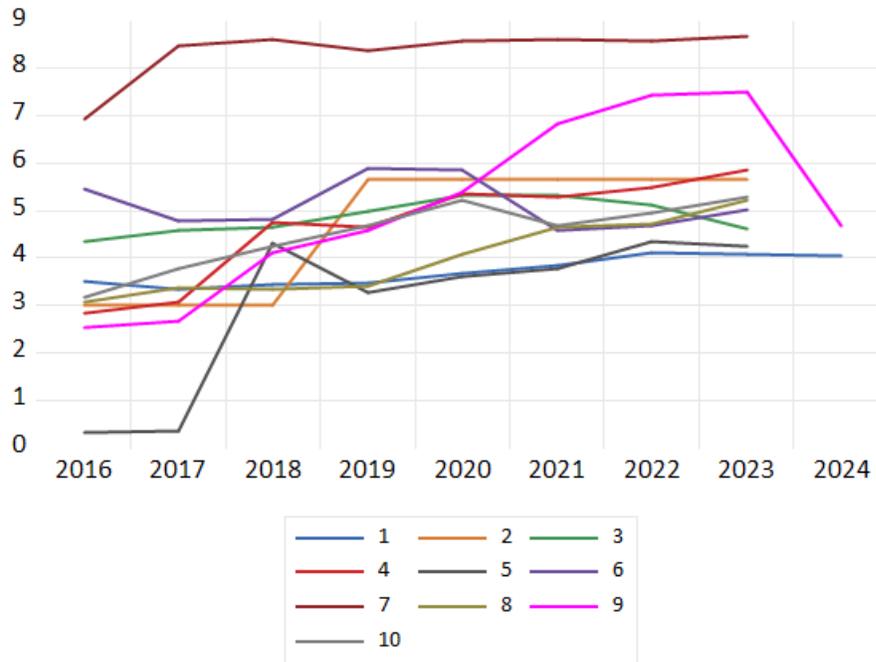
Figure 3

Average Combined ESG Scores
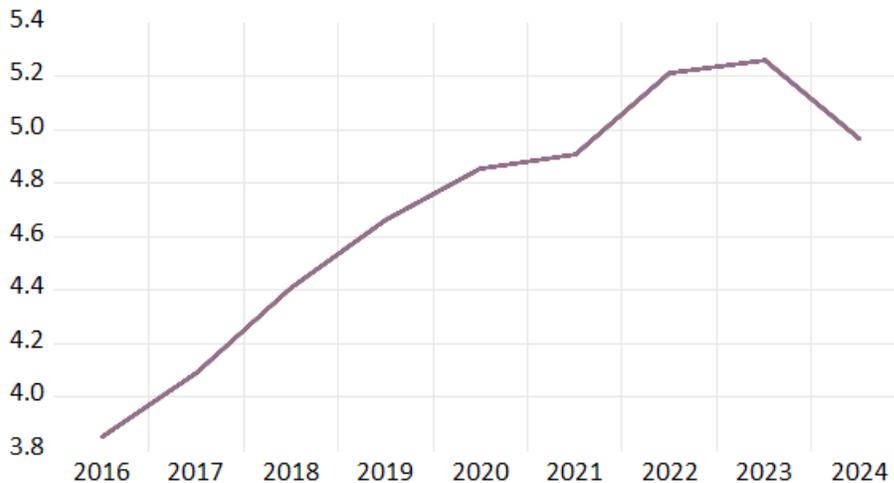
Source: compiled by the author based on research

Figure 3 presents the average combined ESG score across all ten companies over the 2016-2024 period. The results indicate a clear upward trend in average ESG performance from 2016 to 2023, suggesting a gradual strengthening of sustainability practices within the sample. Periods of slower growth or relative plateauing are observed between 2020-2021 and 2022-2023, which coincide with broader economic and operational disruptions during the COVID-19 period, although no causal inference is implied. The decline observed between 2023 and 2024 should be interpreted with caution, as only two out of the ten companies reported ESG data for 2024. Consequently, the average score for year 2024 is heavily influenced by a reduced and potentially unrepresentative subset of firms.

Despite the upward trend in ESG scores observed across most firms, the regression results indicate that these improvements do not translate into statistically significant short-term financial performance effects, suggesting that ESG score gains may reflect enhanced disclosure and policy alignment rather than immediate profitability impacts. To provide more granular insight into the drivers of these trends, Figure 4 presents a disaggregated analysis of the Environmental pillar. The aggregate trend masks considerable variation across ESG dimensions, underscoring the importance of examining individual pillars when assessing SSCM-related performance dynamics.

Figure 4

Environmental Pillar Scores per Company 2016-2024

Note. 1-10 are companies analyzed

Source: compiled by the author based on research

Figure 4 illustrates the evolution of Environmental pillar scores for the ten companies over the 2016-2024 period. Overall, most firms exhibit relatively stable Environmental performance with modest upward trends between 2016 and 2023, suggesting gradual improvements rather than rapid environmental transformation. However, substantial heterogeneity across firms is evident. In particular, Companies 5 and 9 display pronounced increases in their Environmental scores, especially around the 2018-2021 period, indicating more significant changes in environmental practices or disclosures relative to peers. As with previous figures, observations for 2024 should be interpreted with caution due to limited data availability, which may affect the comparability of trends in the final year. These divergent trajectories highlight differences in the pace and depth of environmental integration within firms' supply chains and operational strategies. In addition, Figure 5 presents the combined average Environmental Pillar Scores across all 10 companies.

Figure 5

Average Combined Environmental Pillar Scores
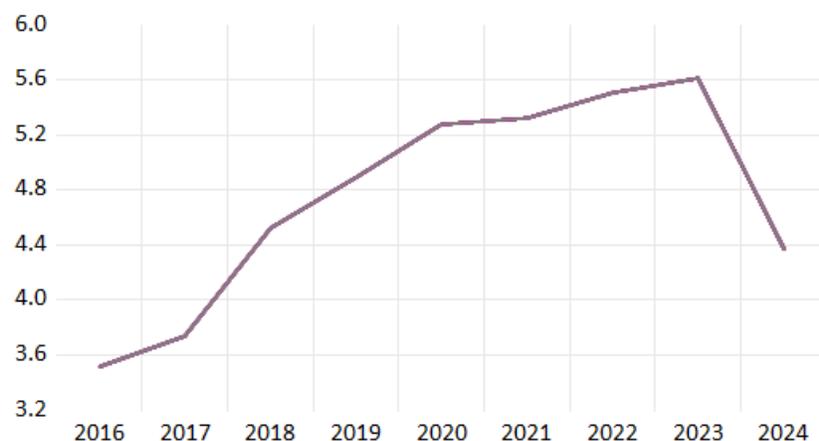
Source: compiled by the author based on research

Figure 5 presents the average combined Environmental pillar score across the 10 companies over the 2016-2024 period. The figure indicates a clear upward trend in average environmental performance from 2016 to 2023, suggesting a gradual strengthening of environmental policies, management systems, and disclosure practices across the sample. Average scores increase steadily between 2016 and 2020, reflecting incremental improvements rather than abrupt changes in environmental performance. A period of slower growth and relative stabilization is observed between 2020 and 2021, coinciding with the Covid-19 pandemic, during which firms may have experienced operational disruptions or shifting strategic priorities. However, no causal inference is implied. From 2021 to 2023, the average Environmental score resumes its upward trajectory, reaching its highest level in 2023, which suggests renewed emphasis on environmental management and sustainability initiatives across firms. The decline observed between 2023 and 2024 should be interpreted with caution, as environmental pillar data for 2024 are available for only a subset of companies. Consequently, the average score in the final year may be disproportionately influenced by firms with lower reported environmental performance, limiting comparability with earlier periods. As with other aggregate ESG indicators, this pattern reflects the unbalanced nature of the panel in the most recent year. When considered alongside emissions-based indicators, the upward trend in Environmental pillar scores contrasts with the observed increases in Scope 1 and Scope 3 emissions, highlighting a potential divergence between environmental management practices and realized emissions outcomes. This finding underscores the importance of complementing ESG score-based measures with quantitative

emissions data when assessing environmental performance within SSCM frameworks. Additionally, Figure 5 highlights important cross-pillar differences in both the level and dynamics of ESG performance.

Figure 6

Governance Pillar Scores per Company 2016-2024
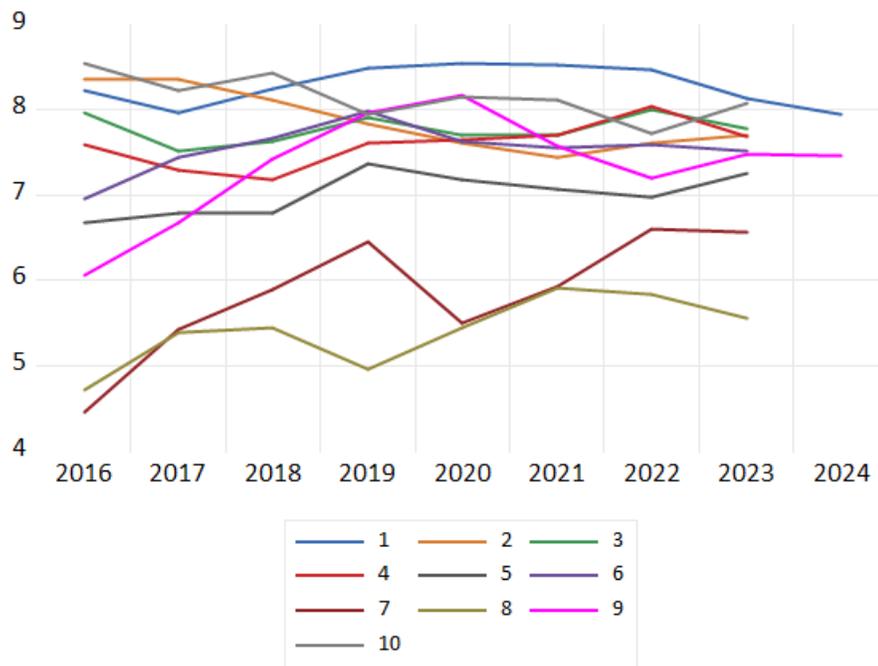

Note. 1-10 are companies analyzed

Source: compiled by the author based on research

Figure 6 presents the evolution of Governance pillar scores for the 10 companies over the 2016-2024 period. Overall, Governance performance appears relatively strong and stable across firms, with most companies reporting scores clustered at the upper end of the scale throughout the observation period. This suggests that governance-related structures, policies, and disclosures were already comparatively well established at the beginning of the period. Despite this general stability, firm-level heterogeneity is clearly observable. Several companies (notably Companies 1, 2, 3, and 6) consistently exhibit high Governance scores, with only modest fluctuations over time. These trajectories indicate incremental improvements rather than structural changes, reflecting mature governance frameworks with limited year-to-year volatility. In contrast, other firms (such as Companies 7 and 8) begin the period with lower Governance scores but demonstrate gradual improvements, particularly between 2017 and 2022, suggesting progressive

strengthening of governance mechanisms and oversight practices. A mild dip or plateau in Governance scores is visible for some companies around the 2019-2021 period. This coincides with the Covid-19 pandemic and may reflect temporary disruptions in board operations, compliance processes, or reporting practices; however, no causal interpretation is implied. As with previous figures, observations for 2024 should be interpreted with caution due to limited data availability. Only a subset of companies report Governance scores in the final year, which may exaggerate apparent changes or mask underlying trends. Taken together, Figure 5 indicates that while Governance performance across the sample is generally high and stable, meaningful differences persist in the pace at which firms enhance governance practices. These findings suggest that governance improvements in SSCM contexts tend to be incremental and path-dependent, reinforcing the importance of longitudinal analysis when assessing firm-level sustainability performance. Figure 7 presents the combined average Governance Pillar Scores across all ten companies.

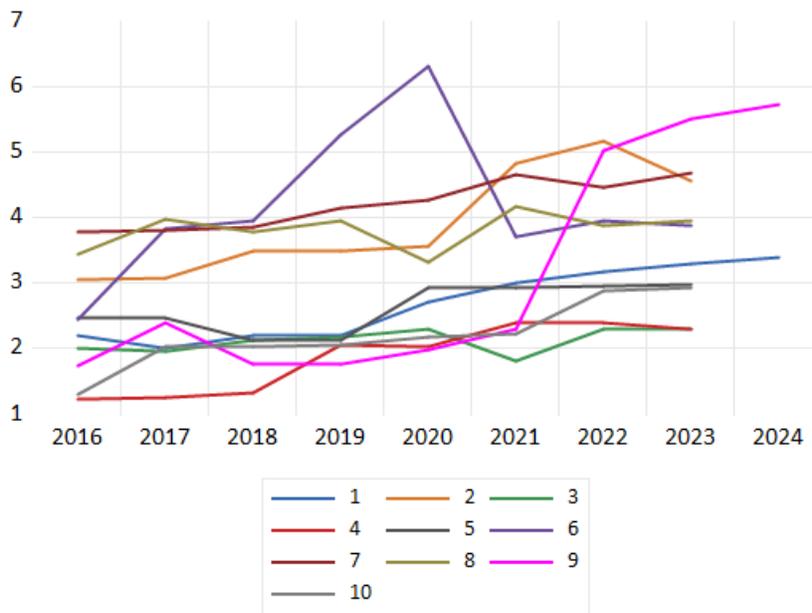**Figure 7**

Average Combined Governance Pillar Scores
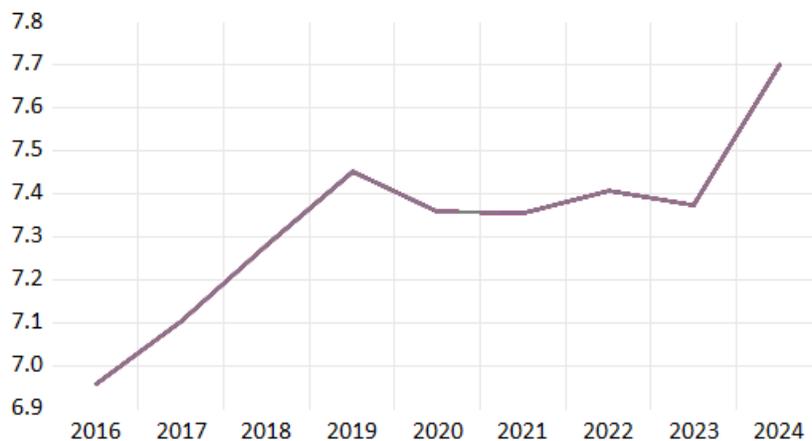
Source: compiled by the author based on research

Figure 7 results indicate a clear upward trend in average governance performance over time, suggesting a gradual strengthening of governance-related structures, policies, and disclosure practices within the sample. Average scores increase steadily between 2016 and 2019, reflecting improvements in board oversight, risk management, and compliance mechanisms across firms. A period of relative stagnation is observed between 2019 and 2021, during which the average governance score slightly declines and then stabilizes. This plateau coincides with

the Covid-19 pandemic period, during which firms may have faced operational disruptions and shifting priorities. However, no causal inference is implied. From 2021 to 2023, the average governance score resumes a modest upward trajectory, indicating renewed incremental improvements across the sample. The sharper increase observed between 2023 and 2024 should be interpreted with caution, as data for 2024 are available for only a subset of firms. Consequently, the average score for the final year may be disproportionately influenced by firms with relatively strong governance performance, limiting comparability with earlier years. While environmental performance exhibits greater cross-firm variability and more pronounced shifts over time, governance performance evolves more steadily, providing an institutional foundation that may support longer-term sustainability initiatives. This aggregate perspective complements the firm-level analysis by highlighting common temporal patterns while underscoring the importance of accounting for data limitations and panel imbalance in recent years. In addition, Figure 8 presents the results of Social Pillar Scores.

Figure 8

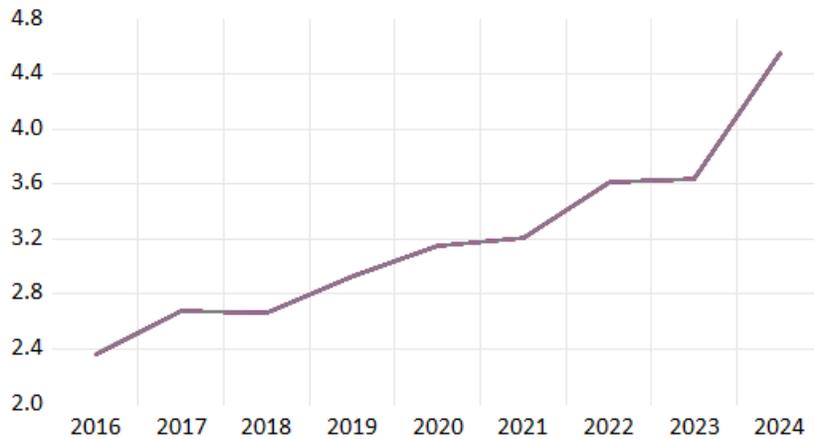*Social Pillar Scores per Company 2016-2024*

Note. 1-10 are companies analyzed

Source: compiled by the author based on research

Figure 8 illustrates the evolution of Social pillar scores for the ten companies over the 2016-2024 period. Compared to the Environmental and Governance dimensions, Social

performance exhibits greater variability across firms and more pronounced fluctuations over time. Overall, several companies demonstrate gradual improvements in Social scores, indicating increased attention to labor practices, employee welfare, stakeholder engagement, and broader social responsibility within supply chain operations. Marked heterogeneity across firms is evident. Some companies (notably Companies 2, 6, and 9) display substantial changes in Social scores over the observation period. In particular, Company 6 experiences a sharp increase in Social performance between 2017 and 2020, followed by a pronounced decline around 2021, suggesting a period of reassessment or changes in social practices or reporting. Similarly, Company 9 shows a relatively modest trajectory until 2021, after which Social scores increase sharply, indicating a more recent intensification of social initiatives or disclosure efforts. In contrast, several firms (such as Companies 1, 4, 5, and 10) exhibit relatively stable Social scores with incremental upward movements, suggesting gradual and sustained improvements rather than abrupt shifts. Temporary declines or plateaus around the 2020-2021 period are observable for multiple companies, coinciding with the COVID-19 pandemic. These fluctuations may reflect disruptions to workforce management, supply chain labor conditions, or data reporting practices during this period; however, no causal inference is implied. As with previous figures, observations for 2024 should be interpreted with caution due to limited data availability across firms. The uneven reporting in the final year may amplify apparent trends or volatility. Overall, Figure 7 highlights that Social pillar performance is more uneven and dynamic than Environmental and Governance dimensions, underscoring the complexity of managing social issues within SSCM frameworks. These findings reinforce the importance of disaggregated ESG analysis, as aggregate ESG scores may obscure substantial variation in social performance trajectories across firms. Figure 9 presents the combined average Social Pillar Scores across all ten companies.

Figure 9

*Average Combined Social Pillar Scores*

Source: compiled by the author based on research

Figure 9 presents the average combined Social pillar score across the ten companies over the 2016-2024 period. The results indicate a clear and sustained upward trend in average Social performance throughout the observation window, suggesting a progressive strengthening of social practices related to labor standards, employee well-being, stakeholder engagement, and supply chain responsibility within the sample. Between 2016 and 2019, the average Social score increased steadily, reflecting gradual improvements across firms. This upward momentum continues through the 2020-2021 period, despite broader economic and operational disruptions associated with the Covid-19 pandemic. However, firm-level volatility remains evident, as shown in Figure 8. From 2021-2022 the growth continues. However, the particularly sharp increase observed between 2023 and 2024 is likely due to there only being 2 firms reporting scores for that period. As with previous aggregate figures, this final-year increase should be interpreted with caution due to limited data availability, as only a subset of firms report Social pillar scores for 2024. Consequently, the average may be disproportionately influenced by firms that exhibit relatively strong social performance, thereby reducing comparability with earlier years. When considered alongside Figures 6 and 7, Figure 8 underscores the dynamic nature of Social performance within SSCM-related ESG dimensions. While Governance scores evolve more gradually and Environmental scores display moderate variability, Social scores demonstrate stronger aggregate growth alongside higher firm-level dispersion. This pattern highlights the increasing salience of social issues within supply chains and reinforces the importance of examining both firm-level and aggregate trends when assessing sustainability performance.

The relatively stable and high Governance scores observed across firms are consistent with the regression results, which show limited variation in financial outcomes associated with governance improvements, except for a significant negative relationship with ROE. This may reflect increased compliance and oversight costs that do not immediately generate shareholder returns. In addition, Figure 10 presents the results of GHG Scope 1.

Figure 10

GHG Scope 1 per Company 2016-2024
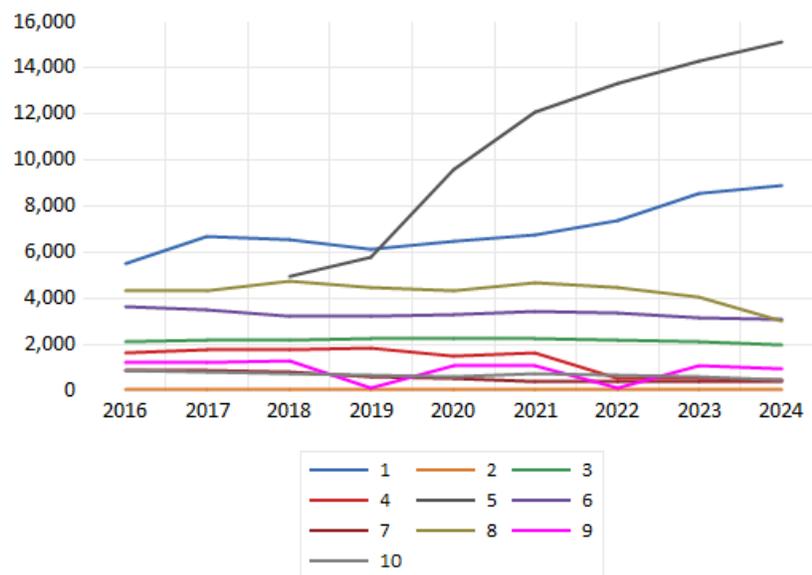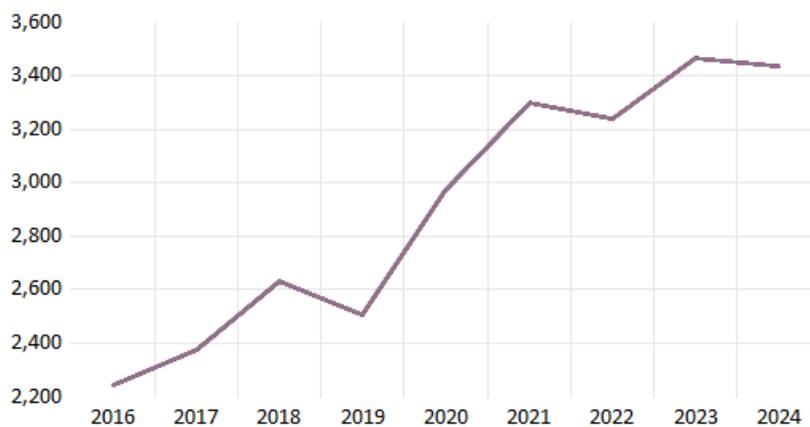

Note. 1-10 are companies analyzed

Source: compiled by the author based on research

Figure 10 presents the evolution of Scope 1 GHG emissions for the 10 companies over the 2016-2024 period. Scope 1 emissions, which capture direct emissions from owned or controlled sources, exhibit substantial heterogeneity across firms, both in absolute levels and in temporal trajectories. This variation reflects differences in firm size, operational intensity, production processes, and sector-specific characteristics. Several companies display relatively stable Scope 1 emission levels over time, with only modest fluctuations. For example, Companies 3, 4, 6, and 7 maintain comparatively low and stable emissions throughout the period, suggesting limited changes in direct operational emissions or gradual efficiency improvements. In contrast, other firms show pronounced increases in Scope 1 emissions. Most notably, Company 5 exhibits a sharp and sustained rise from 2019 onwards, indicating a significant expansion in emission-

intensive activities, changes in production scale, or improved reporting coverage. Company 1 also demonstrates a clear upward trend in Scope 1 emissions across the period, particularly after 2019, while Company 8 shows a gradual decline after reaching a peak around 2021. These divergent patterns underscore the uneven pace at which firms address direct emissions within their operations. Temporary declines or volatility around the 2020-2021 period are observable for some companies, coinciding with the Covid-19 pandemic, which may have affected production levels, energy use, or reporting practices; however, no causal inference is implied. Overall, Figure 9 highlights substantial cross-sectional and longitudinal variation in Scope 1 emissions, reinforcing the importance of firm-level analysis when assessing environmental performance within SSCM frameworks. These results suggest that while some firms may be making progress in managing direct emissions, others continue to experience rising operational emissions, pointing to uneven integration of emission reduction strategies across the sample. Figure 11 presents the combined average GHG Scope 1 across all 10 companies.

Figure 11

Average Combined GHG Scope 1

Source: compiled by the author based on research

Figure 11 presents the average combined Scope 1 GHG emissions across the ten companies over the 2016-2024 period. The figure indicates an overall upward trend in average direct emissions, suggesting that, at the aggregate level, Scope 1 emissions have increased over time within the sample. Average emissions rise steadily from 2016 to 2018, followed by a temporary decline in 2019. A pronounced increase is observed between 2019 and 2021, during which average Scope 1 emissions rise sharply. This pattern coincides with the Covid-19 period,

during which firms may have experienced changes in production intensity, energy use, or reporting coverage. However, no causal inference is implied. Following a slight moderation in 2022, average emissions increase again in 2023, before stabilizing or marginally declining in 2024. As with earlier aggregate figures, observations for 2024 should be interpreted with caution. Data availability in the final year may be limited or uneven across firms, potentially affecting the representativeness of the average. Moreover, the aggregate trend masks substantial heterogeneity at the firm level, as illustrated in Figure 9, where some companies exhibit declining or stable emissions while others experience significant increases. When considered alongside the Environmental pillar results presented earlier (Figures 4 and 6), Figure 10 highlights a potential divergence between environmental performance scores and emissions-based outcomes. While Environmental pillar scores generally improve over time, average Scope 1 emissions increase, suggesting that improvements in environmental policies, disclosures, or management systems may not immediately translate into reductions in direct operational emissions. This underscores the importance of complementing ESG scores with emissions data when assessing SSCM-related environmental performance. Additionally, Figure 12 presents the results of GHG Scope 2.
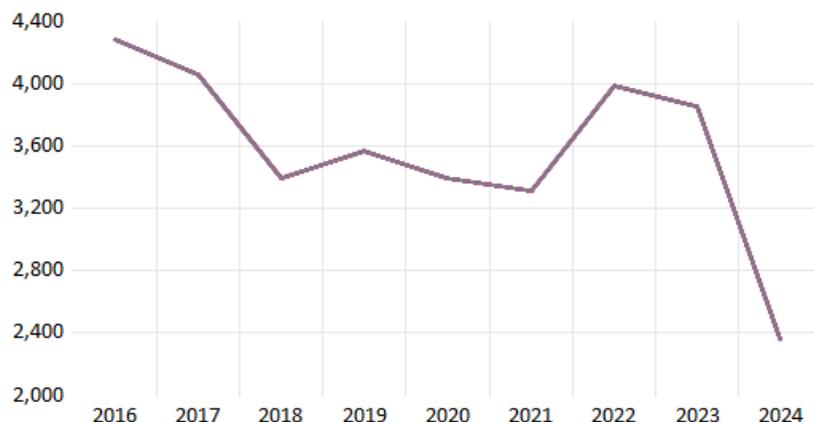
Figure 12

GHG Scope 2 per Company 2016-2024
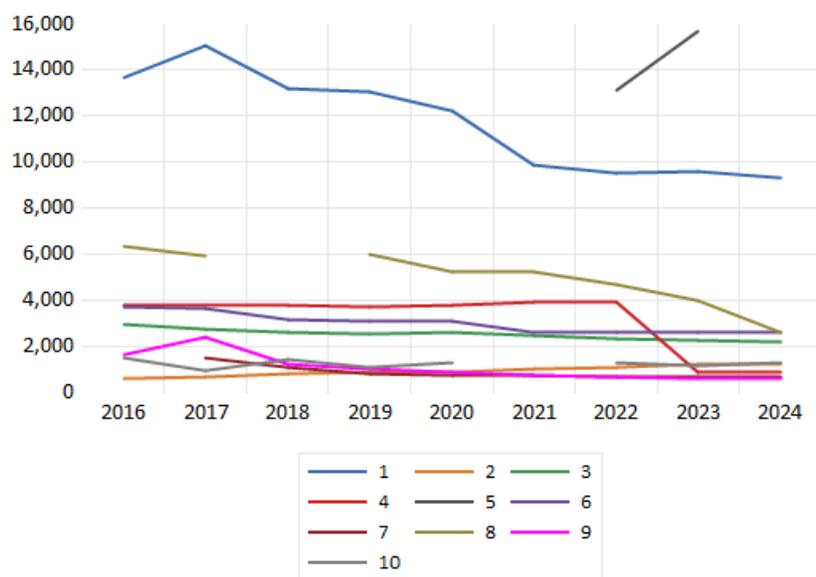
Note. 1-10 are companies analyzed

Source: compiled by the author based on research

Figure 12 illustrates the evolution of Scope 2 GHG emissions for the 10 companies over the 2016-2024 period. Scope 2 emissions, which capture indirect emissions from purchased electricity, heat, and steam, display substantial heterogeneity across firms in both magnitude and trend. This variation reflects differences in energy intensity, sourcing strategies, and the extent of renewable energy adoption across companies. Several firms demonstrate a clear downward trend in Scope 2 emissions over time. Notably, Company 1 shows a sustained decline from 2017 onwards, suggesting improvements in energy efficiency, shifts toward cleaner energy sources, or changes in operational scale. Similarly, Company 8 exhibits a gradual reduction in Scope 2 emissions throughout the period, particularly after 2019. These trajectories are consistent with increased corporate emphasis on energy management and decarbonization strategies. In contrast, other firms display relatively stable or modestly fluctuating Scope 2 emissions, indicating limited changes in indirect energy-related emissions. A small number of companies experience short-term increases or volatility, particularly around the 2021-2022 period, which may be associated with changes in production activity, energy procurement, or reporting practices. However, no causal inference is implied. As with previous emissions figures, observations for 2024 should be interpreted with caution due to potential data limitations and uneven reporting across firms. Importantly, when compared with Scope 1 emissions (Figures 9 and 10), Scope 2 emissions appear to decline more consistently for several firms. This contrast suggests that reductions in purchased-energy emissions may be more readily achievable in the short to medium term than reductions in direct operational emissions. Overall, Figure 11 highlights divergent firm-level strategies in managing indirect emissions and underscores the importance of distinguishing between emission scopes when evaluating environmental performance within SSCM frameworks. The results reinforce the need to complement ESG score-based analyses with disaggregated emissions data to capture substantive environmental outcomes. Figure 13 presents the combined average GHG Scope 2 across all ten companies.

Figure 13

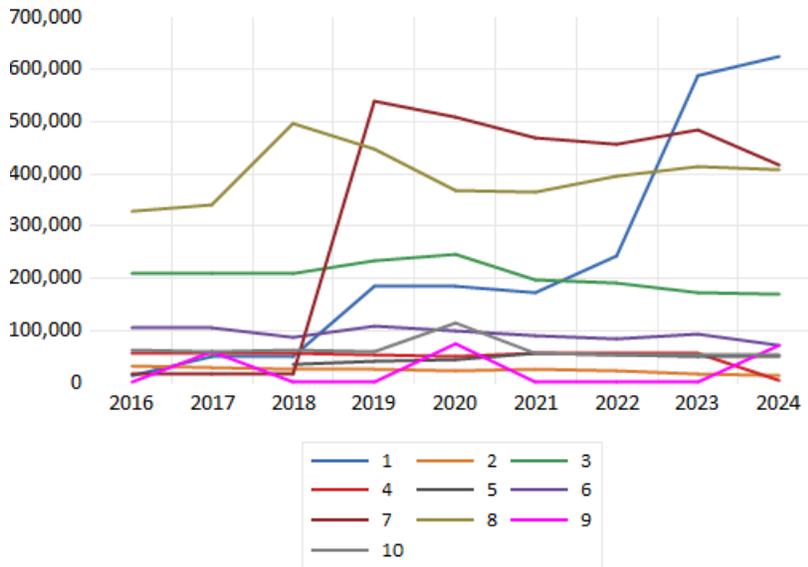*Average Combined GHG Scope 2*

Source: compiled by the author based on research

Figure 13 presents the average combined Scope 2 GHG emissions across the 10 companies over the 2016-2024 period. In contrast to the upward trend observed for Scope 1 emissions, the aggregate Scope 2 trajectory displays a general downward pattern, indicating a reduction in indirect emissions associated with purchased electricity, heat, and steam across the sample. Between 2016 and 2018, average Scope 2 emissions decline sharply, suggesting early improvements in energy efficiency or a shift towards lower-carbon energy sources. This is followed by a period of relative stabilization between 2018 and 2021, during which average emissions fluctuate modestly. A temporary increase is observed around 2022-2023, but this is possibly influenced by the inclusion of company 5 which only reported their scope 2 emmisions for that time. The pronounced decline observed between 2023 and 2024 should be interpreted with particular caution, as emissions data for 2024 may be available for only a subset of firms. Consequently, the average for the final year may be disproportionately influenced by companies with lower reported Scope 2 emissions, limiting comparability with earlier periods. This limitation mirrors the unbalanced panel structure noted in previous aggregate analyses. When considered alongside Figures 10 and 11, Figure 12 highlights a clear divergence between direct and indirect emissions trends. While average Scope 1 emissions increase over time, Scope 2 emissions generally decline, suggesting that firms may find it more feasible to reduce purchased-energy emissions, through energy sourcing decisions or efficiency gains, than to curb direct operational emissions. This divergence underscores the importance of scope-specific analysis when

evaluating environmental performance within SSCM frameworks. Additionally, Figure 14 presents the results of GHG Scope 3.

Figure 14

GHG Scope 3 per Company 2016-2024
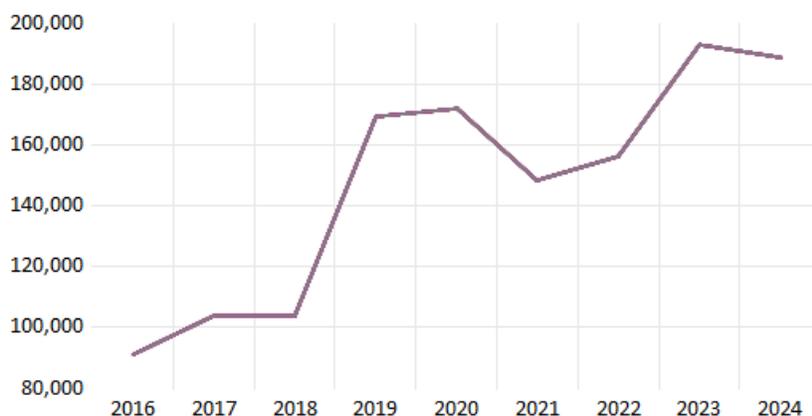

Note. 1-10 are companies analyzed

Source: compiled by the author based on research

Figure 14 illustrates the evolution of Scope 3 GHG emissions for the ten companies over the 2016-2024 period. Scope 3 emissions, which encompass indirect emissions across the value chain (including upstream and downstream supply chain activities), exhibit substantial heterogeneity across firms and are markedly higher in magnitude than Scope 1 and Scope 2 emissions. This reflects the broader and more complex nature of Scope 3 accounting, which is highly sensitive to firm size, supply chain structure, and reporting scope. Several companies display pronounced increases in Scope 3 emissions over time. Most notably, Company 1 shows a sharp and sustained rise from 2019 onwards, indicating either a significant expansion of value chain activities, improved emissions coverage, or enhanced disclosure practices. Similarly, Company 4 exhibits a steep increase around 2019, followed by a gradual decline thereafter, suggesting a potential one-off adjustment in reporting boundaries or changes in supply chain configuration. Other firms demonstrate more moderate or stable trajectories. Companies 3 and 8 maintain relatively high but comparatively stable Scope 3 emission levels across the period, with only gradual fluctuations. In contrast, several companies (including Companies 2, 5, 6, and 7)

report substantially lower Scope 3 emissions, with limited variation over time, which may reflect differences in business models, supply chain complexity, or the extent of Scope 3 disclosure. Temporary declines or volatility are observable around the 2020–2021 period for multiple firms, coinciding with the Covid-19 pandemic. These fluctuations may be associated with disruptions in supply chain activity, demand contraction, or changes in reporting practices. However, no causal inference is implied. As with other emissions figures, observations for 2024 should be interpreted with caution due to potential data limitations and uneven reporting across firms. Overall, Figure 13 highlights the significant cross-firm variation and high volatility characteristic of Scope 3 emissions. These findings underscore the critical importance of Scope 3 considerations in SSCM-related environmental performance, as value chain emissions constitute a substantial share of total GHG impact and present distinct measurement and management challenges compared to direct and energy-related emissions. Figure 15 presents the combined average GHG Scope 3 across all 10 companies.

Figure 15

Average Combined GHG Scope 3

Source: compiled by the author based on research

Figure 15 presents the average combined Scope 3 GHG emissions across the 10 companies over the 2016-2024 period. The figure indicates a pronounced upward trend in average value chain emissions, highlighting the growing significance of Scope 3 emissions within the overall environmental footprint of the sample. Between 2016 and 2018, average Scope 3 emissions increase moderately, followed by a sharp rise between 2018 and 2019. This step change may reflect expanded Scope 3 reporting coverage, improved data availability, or increased supply chain activity across firms; however, no causal inference is implied. After

reaching a peak around 2019-2020, average emissions decline temporarily in 2021, coinciding with the Covid-19 period, before resuming an upward trajectory between 2022 and 2023. As with other aggregate emissions figures, the unbalanced nature of the panel may disproportionately influence the average, reducing comparability with earlier years. When considered alongside Figures 10 and 12, Figure 14 highlights a clear divergence across emission scopes. While average Scope 2 emissions generally decline and Scope 1 emissions exhibit moderate increases, Scope 3 emissions rise substantially over time, underscoring the dominant role of supply chain and downstream activities in firms' total GHG profiles. This pattern reinforces the central importance of SSCM-related interventions, such as supplier engagement, logistics optimization, and product lifecycle management, in addressing long-term emissions reductions. Overall, Figure 14 emphasizes that improvements in ESG scores or reductions in direct and energy-related emissions do not necessarily translate into lower value chain emissions. This finding highlights the complexity of Scope 3 management and the need for more comprehensive and coordinated sustainability strategies across firm boundaries.

The divergence between improving Environmental pillar scores and rising Scope 1 and Scope 3 emissions provides important context for the regression findings. While firms appear to strengthen environmental policies and management systems, these changes do not consistently translate into reductions in direct or value-chain emissions. In contrast, Scope 2 emissions (more directly linked to energy sourcing decisions) exhibit clearer downward trends for several firms and are the only emissions category showing a statistically significant association with financial performance. This suggests that operationally controllable sustainability actions may have more immediate financial relevance than broader supply-chain interventions.

To summarize, the graphical analysis reveals a nuanced picture of sustainability performance across the sample over the 2016-2024 period. Overall ESG scores exhibit a gradual upward trend, indicating broad improvements in sustainability performance, albeit with notable heterogeneity across firms and temporary stagnation around the 2020-2021 period. Disaggregated pillar analysis shows divergent dynamics: Governance scores remain relatively high and stable, suggesting mature institutional frameworks, while Environmental scores improve modestly and Social scores display stronger growth but greater firm-level volatility. Aggregate pillar trends reinforce these findings, with steady increases in average Governance and Social scores and more moderate gains in Environmental performance. In contrast to these score-based improvements, emissions data reveal mixed environmental outcomes. Average Scope 1 emissions increase over time, indicating rising direct operational emissions, whereas Scope 2 emissions generally decline, suggesting progress in reducing purchased-energy emissions. Most

strikingly, Scope 3 emissions rise substantially at both firm and aggregate levels, highlighting the growing dominance of value chain emissions within firms' total GHG footprints. Temporary disruptions and volatility are observable across several indicators around the Covid-19 period, though no causal inference is implied. Across all figures, limited data availability in 2024 introduces panel imbalance and warrants caution in interpreting end-period trends. Overall, the combined evidence suggests that while firms have strengthened ESG policies, governance structures, and social practices, these improvements have not yet translated into consistent reductions in total emissions, particularly within supply chains, underscoring the critical importance of SSCM-focused interventions to address value chain emissions and achieve substantive environmental outcomes. To provide visual context for the regression results, scatterplots were generated to explore the relationships between ESG scores and ROA, and between Scope 2 GHG emissions and operating margin (Figures 16-17). Each point represents a firm-year observation, with distinct markers denoting individual companies.

Figure 16 provides a firm-level exploratory visualization of ESG score relationship with ROA, highlighting cross-sectional heterogeneity.
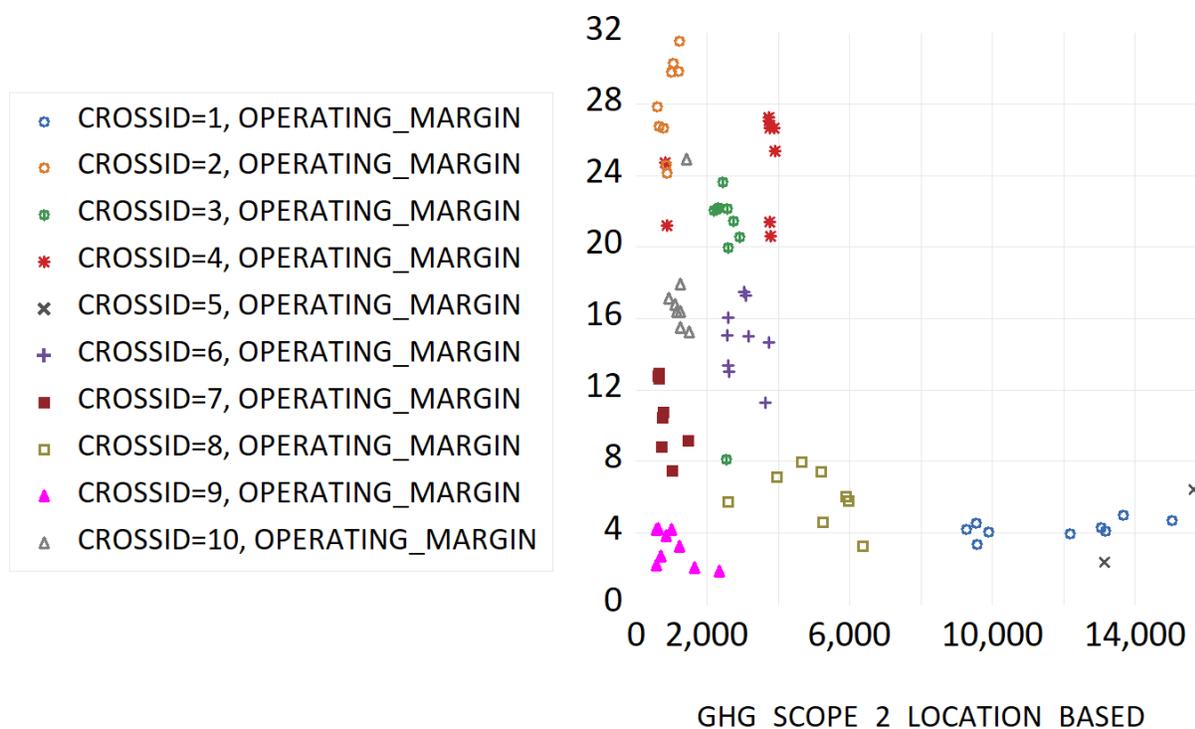
Figure 16

Scatterplot for ESG Score Relationship with ROA

Source: compiled by the author based on research

The scatterplot illustrates the relationship between ESG scores and ROA across the 10 companies in the sample over the observation period. Each marker represents a firm-year observation, with different symbols identifying individual companies. The ESG-ROA scatterplot (Figure 16) suggests a generally positive association, as higher ESG scores tend to coincide with higher ROA values for several firms. However, the relationship is non-linear and highly heterogeneous, with considerable variation across companies. This dispersion illustrates why the regression results do not show statistically significant coefficients for ESG scores, despite the directional positive effect observed in the descriptive data. Firm-level dispersion is pronounced. Some companies (notably Companies 2, 4, and 10) exhibit relatively high ROA values at moderate to high ESG score levels, suggesting that stronger sustainability performance may coexist with superior profitability in these cases. In contrast, other firms (such as Companies 7 and 9) display comparatively low ROA despite similar or higher ESG scores, indicating that ESG performance alone does not guarantee improved financial outcomes. This divergence highlights the influence of firm-specific characteristics, operational structures, and industry conditions. At lower ESG score levels, ROA values appear more tightly clustered, whereas greater dispersion is observed as ESG scores increase. This pattern suggests that while higher ESG engagement may create opportunities for improved financial performance, outcomes vary widely depending on firm-level implementation and context. Negative or near-zero ROA observations are also present, particularly among firms with lower ESG scores, reflecting episodes of weaker financial performance that may be driven by factors unrelated to sustainability practices. Overall, the scatterplot provides exploratory evidence of a potential positive ESG-ROA relationship, while simultaneously underscoring the importance of accounting for cross-firm heterogeneity and temporal dynamics. The observed variation reinforces the need for multivariate panel regression analysis to formally assess the ESG-financial performance relationship while controlling for firm-specific effects, rather than relying solely on visual inspection. Moreover, the visualization analysis for the relationship between Scope 2 and Operational Margin will be provided in Figure 17.

Figure 17

Scatterplot for Scope 2 Relationship with Operational Margin

Legend:
- CROSSID=1, OPERATING_MARGIN
- CROSSID=2, OPERATING_MARGIN
- CROSSID=3, OPERATING_MARGIN
- CROSSID=4, OPERATING_MARGIN
- CROSSID=5, OPERATING_MARGIN
- CROSSID=6, OPERATING_MARGIN
- CROSSID=7, OPERATING_MARGIN
- CROSSID=8, OPERATING_MARGIN
- CROSSID=9, OPERATING_MARGIN
- CROSSID=10, OPERATING_MARGIN

GHG_SCOPE_2_LOCATION_BASED

Source: compiled by the author based on research

The Scope 2 relationship with Operating Margin scatterplot (Figure 17) reveals substantial variation across firms in both emissions and profitability. While firms with lower Scope 2 emissions span a wide range of operating margins, some higher-emission firms also achieve moderate profitability. This heterogeneity helps explain why Scope 2 was the only emissions measure showing consistent statistical significance in regression models, highlighting the importance of firm-specific operational factors in determining financial outcomes. Firms with relatively low Scope 2 emissions are observed across a wide range of operating margins, from low to very high values, while firms with higher Scope 2 emissions tend to cluster at moderate or lower operating margin levels. This pattern suggests that lower indirect emissions do not uniformly correspond to higher profitability, nor do higher emissions necessarily imply weaker operating performance. Firm-level clustering is pronounced. Some companies (notably Companies 2, 4, and 3) display high operating margins at comparatively low Scope 2 emission levels, whereas others (such as Companies 1 and 8) exhibit higher Scope 2 emissions but only modest operating margins. In contrast, firms with consistently low operating margins (for example, Companies 7 and 9)

generally report low Scope 2 emissions, reflecting differences in scale, operational structure, or energy intensity rather than a direct emissions-profitability trade-off. The absence of a dominant trend line, combined with clear firm-specific groupings, underscores the importance of controlling for unobserved heterogeneity when examining the relationship between emissions and financial performance. As such, Figure 17 should be interpreted as exploratory evidence, highlighting variation across firms rather than establishing a systematic association between Scope 2 emissions and operating margin. These patterns reinforce the need for panel regression techniques to formally assess whether reductions in indirect emissions are associated with changes in operating profitability once firm-specific and time-specific factors are accounted for.

Overall, these scatterplots provide exploratory visual evidence that supports the regression approach: they underscore firm-level heterogeneity, non-linear patterns, and the need for panel regression models that control for unobserved, time-invariant characteristics. The plots complement the descriptive and regression analyses by clarifying why some sustainability indicators do not exhibit robust short-term financial effects, despite general improvements in ESG scores and sustainability practices.

3.5. Discussion

The findings of this study reveal nuanced and dimension-specific effects of SSCM (ESG score, Environmental Pillar, Social Pillar, Governance Pillar; GHG Scope 1, Scope 2, Scope 3) on corporate financial performance (ROA, ROE, Operational Margin), suggesting that sustainability initiatives do not have uniform or immediate impacts. Instead, the influence of ESG and GHG measures depends on the type of initiative, the operational channel, and the temporal horizon of benefits. Table 15 summarizes the validation of hypotheses.

Table 15

Validation of Hypotheses

Hypothesis	Dependent Variable	Statistically Significant Variable(s)	Discovered Effect	Expected Effect	Validation
H1a	ROA	None (ESG score not significant)	+	+	Not supported
H1b	ROE	None (ESG score not significant)	+	+	Not supported
H1c	Operating Margin	None (ESG score not significant)	+	+	Not supported
H2a	ROA	None (Environmental, Social, Governance)	+ / + / -	+	Not supported
H2b	ROE	Governance Pillar	-	+	Not supported
H2c	Operating Margin	None (Environmental, Social, Governance)	+	+	Not supported
H3a	ROA	Scope 2 emissions	+	-	Not supported
H3b	ROE	Scope 2 emissions	+	-	Not supported
H3c	Operating Margin	Scope 2 emissions	+	-	Not supported

Source: compiled by the author based on research

The results suggest that aggregate ESG performance does not exhibit statistically significant short-term effects on profitability across ROA, ROE, and operating margin. Although the coefficients were consistently positive, indicating a potential beneficial trend, the lack of statistical significance implies that overall ESG scores may not immediately translate into accounting gains. This finding aligns with prior research documenting mixed relationships between ESG and financial performance, particularly over short time horizons (Sachin & Rajesh, 2022; Li et al., 2025). From an RBV and NRBV perspective, sustainability-related capabilities, such as energy-efficient processes, stakeholder engagement practices, and governance mechanisms, often require substantial investments and integration into complex operational and supply-chain structures before their financial benefits are realized (Hart, 1995). Consequently, the value generated by ESG initiatives may be latent, producing long-term competitive advantages rather than immediate accounting improvements. A further consideration concerns the construction of aggregate ESG scores, which combine heterogeneous elements, including

policies, disclosures, operational outcomes, and controversy indicators. Such aggregation may mask dimension-specific effects, as positive performance in one area (e.g., energy efficiency) could be offset by costs or weaknesses in another (e.g., governance implementation), reducing observable short-term financial impacts. Prior methodological critiques emphasize that aggregated ESG measures can limit comparability across firms and providers, and obscure relationships that may exist at the pillar or operational level (Friede et al., 2015; Truant et al., 2024). While the current study addresses this issue through pillar-level analysis, the remaining mixed results suggest that further disaggregation is necessary. For example, separating disclosure intensity from substantive operational outcomes, or considering dimension-specific GHG emissions, could clarify the pathways through which sustainability efforts influence profitability (Gao et al., 2023). Disaggregating ESG into Environmental, Social, and Governance pillars reveals additional complexity. The environmental and social pillars exhibit positive but statistically insignificant relationships with financial performance. This suggests that initiatives such as operational efficiency improvements, energy management, employee engagement, and stakeholder relationship building may require longer time horizons to affect accounting returns, consistent with SSCM research emphasizing delayed or indirect benefits (Golicic & Smith, 2013; Gill et al., 2024). Moreover, these effects may interact with firm size, sectoral characteristics, and production intensity, which could obscure short-term statistical significance. In contrast, governance performance demonstrates a statistically significant negative association with ROE, suggesting that investments in governance mechanisms, such as establishing oversight committees, compliance systems, or transparency initiatives, can temporarily reduce shareholder returns. This pattern is theoretically consistent with the ''short-term cost, long-term benefit'' logic, in which governance improvements require upfront resource allocation and managerial attention but may enhance risk mitigation, organizational resilience, and long-term value creation (Al Amosh et al., 2022; Dai et al., 2021). Scatterplots (Figures 16-17) provide visual evidence of substantial firm-level heterogeneity and non-linear patterns. For ESG scores, Figure 16 shows that while higher ESG performance often coincides with higher ROA for some firms, several companies deviate from this trend, illustrating why aggregate ESG coefficients are not statistically significant. Similarly, the Scope 2 relationship with Operating Margin scatterplot (Figure 17) highlights firm-specific operational differences and clustering, reinforcing that short-term financial effects of sustainability initiatives are context-dependent and may be masked in pooled regression models. From a theoretical standpoint, these findings highlight the interplay between internal capabilities and external pressures. While RBV/NRBV suggests that sustainability-related resources are valuable strategic assets, their financial payoff depends on time horizons,

operational focus, and contextual factors. Stakeholder and institutional pressures may drive SSCM adoption, but the short-term accounting effects appear muted. Taken together, the analysis underscores that aggregate ESG measures may be insufficient to capture the nuanced, operationally mediated effects of SSCM on profitability. Instead, disaggregated analyses, focusing on ESG pillars, operational initiatives, and GHG emissions, are necessary to understand the specific channels through which sustainability initiatives impact corporate financial performance. These insights emphasize that ESG and SSCM investments function primarily as strategic, long-term capabilities, rather than immediate profit drivers, highlighting the importance of a context-sensitive and mechanism-oriented approach in both research and practice.

In contrast, governance performance shows a statistically significant negative association with ROE, suggesting that stronger governance mechanisms may initially depress short-term shareholder returns. This result is theoretically interpretable and empirically plausible. Governance-enhancing measures, such as establishing ESG oversight committees, strengthening compliance systems, improving transparency, formalizing internal control mechanisms, and integrating sustainability oversight into strategic decision-making, require upfront investment in both financial and managerial resources. Such investments may temporarily divert attention from revenue-generating operations, resulting in lower ROE during the implementation phase (Al Amosh et al., 2022; Pérez Estébanez & Sevillano Martín, 2025). From a temporal perspective, this pattern aligns with the "short-term cost, long-term benefit" logic. While governance improvements may appear costly initially, they can enhance risk management, regulatory compliance, stakeholder trust, and operational resilience, ultimately supporting sustainable competitive advantage. In this sense, governance interventions function as foundational enablers of SSCM, facilitating the successful implementation of environmental and social initiatives that may only translate into financial gains over longer horizons. These results resonate with the RBV and NRBV frameworks, where governance capabilities constitute strategic resources whose value emerges over time as they integrate with other firm capabilities, such as operational efficiency and innovation capacity (Carter & Rogers, 2008; Hart, 1995). Moreover, governance may indirectly affect financial outcomes through its influence on risk exposure and capital costs. Firms with robust governance structures often benefit from lower cost of capital, improved investor confidence, and reduced operational risks, which may not be fully captured in short-term accounting metrics such as ROE. This finding also aligns with stakeholder and institutional theory perspectives, highlighting that governance mechanisms serve both as legitimizing structures in the eyes of regulators, investors, and customers, and as internal coordination tools that enable complex SSCM initiatives to be implemented effectively. The

analysis of GHG emissions further illuminates the operational channels linking SSCM to financial performance. In this study, Scope 2 (location-based) emissions are positively and significantly associated with ROA, ROE, and operating margin, whereas Scope 1 and Scope 3 emissions are not. While higher emissions are commonly interpreted as inefficiency, Scope 2 emissions primarily reflect electricity and energy consumption, which often correlates with firm scale, production intensity, and capital-intensive operations. From this perspective, higher Scope 2 emissions may indicate larger or more productive operations generating higher value-added output and stronger margins, rather than poor environmental management (Bisceglia, 2024; Gill et al., 2024). Prior research emphasizes that the relationship between emissions and financial performance is often confounded by operational scale, sectoral characteristics, and production intensity (Geng et al., 2023; Qorri et al., 2021). These findings highlight the importance of careful measurement choices in SSCM research: absolute emissions may reflect firm size rather than operational inefficiency, whereas normalized metrics, such as emissions per unit of revenue, assets, or production output, could provide a clearer picture of environmental efficiency. Additionally, incorporating interaction terms with firm size, industry, or operational intensity may improve analytical robustness and help disentangle scale effects from efficiency effects. In contrast, Scope 1 and Scope 3 emissions do not exhibit statistically significant relationships with financial performance. The lack of significance for Scope 3 aligns with prior literature emphasizing the measurement challenges of upstream supply-chain emissions, which are often estimated or modeled due to multi-tier complexity, data incompleteness, and inconsistent reporting frameworks (Bisceglia, 2024; Gill et al., 2024; Singh et al., 2023). Although Scope 3 emissions often account for the largest share of a firm's carbon footprint, short-term accounting measures may not capture their impact, underscoring limitations in current ESG and GHG reporting practices. These null findings highlight that short-term financial metrics may underestimate the value of upstream sustainability initiatives, which often produce benefits indirectly or over longer time horizons. From a theoretical standpoint, these findings illustrate the interplay between internal capabilities and external pressures emphasized by RBV/NRBV, stakeholder theory, and institutional theory. While sustainability-related resources and capabilities, such as governance structures, environmental management systems, and operational efficiencies, can generate competitive advantage, short-term accounting-based performance effects may be muted, particularly for governance and social initiatives. Stakeholder expectations, regulatory pressures, and industry norms often drive the adoption of SSCM practices. However, the translation into financial outcomes depends on temporal dynamics, operational integration, and contextual factors, including firm size, industry characteristics, and geographic regulatory regimes. Collectively, these findings reinforce the

notion that SSCM influences corporate performance through multiple, mechanism-specific pathways. Aggregate ESG scores alone may not reliably predict short-term accounting returns, while operational indicators such as Scope 2 emissions can reveal tangible short-term financial benefits. Governance-focused initiatives may temporarily reduce ROE, reflecting the temporal trade-off between implementation costs and long-term strategic value creation. Notably, the results highlight the need to analyze SSCM at multiple levels of granularity, incorporating ESG pillars, GHG emissions, and operational intensity metrics, to capture how sustainability practices affect firm performance accurately.

The inclusion of one-year lagged ESG and GHG variables provides additional insights into the temporal dimension of SSCM and sustainability-financial performance relationships. Comparing the one-year lagged models with contemporaneous results shows that the overall patterns remain consistent, confirming that short-term financial effects are limited for both aggregate ESG and Scope 3 emissions. Lagged ESG scores remain positive but statistically insignificant across ROA, ROE, and operating margin, consistent with the baseline fixed-effects results. This reinforces the interpretation that improvements in ESG performance do not necessarily translate into immediate accounting gains, highlighting the delayed payoff nature of sustainability investments. Similarly, lagged Scope 3 emissions show negative but non-significant coefficients, aligning with contemporaneous results and reflecting the operational complexity and reporting challenges inherent in upstream supply chains. These findings are theoretically consistent with RBV and NRBV perspectives, which posit that sustainability-related resources and capabilities contribute to long-term competitive advantage rather than short-term profitability. Practically, the lagged analysis suggests that firms should manage expectations regarding the financial impact of ESG and SSCM initiatives, integrating sustainability investments into multi-year strategic planning and performance monitoring frameworks. Moreover, testing lagged variables mitigates concerns of reverse causality, whereby more profitable firms might invest disproportionately in sustainability initiatives. Taken together, the lagged models corroborate the primary results, emphasizing that SSCM and ESG practices function as strategic, long-term capabilities and underscoring the importance of adopting a time-aware perspective in both research and managerial decision-making. Future research could extend this approach by exploring longer lag structures (e.g., two- or three-year lags) to capture delayed effects more fully, particularly for upstream supply-chain impacts such as Scope 3 emissions.

In conclusion, this study advances the understanding of SSCM by demonstrating that the financial impact of sustainability initiatives is context-dependent, dimension-specific, and time-sensitive. While aggregate ESG scores may not translate into immediate profitability, targeted

operational interventions and governance investments function synergistically, laying the groundwork for long-term value creation, risk mitigation, and strategic resilience. This perspective underscores that SSCM requires a strategic, integrative, and temporally informed approach to generate both financial and sustainability outcomes.

3.6. Limitations, Future Research, and Implications

Several limitations should be acknowledged. The small sample size (10 firms) and relatively short panel period (2016-2024) may constrain statistical power and generalizability. Potential endogeneity may exist, as more profitable firms could be better positioned to invest in sustainability initiatives. Additionally, inconsistencies or gaps in Scope 3 reporting may limit the ability to fully capture supply-chain environmental impacts. Only one-year lagged effects were tested; longer lags (2-3 years) could reveal additional delayed impacts. Future research could address these limitations by analyzing larger, more diverse samples over longer time horizons, incorporating qualitative outcomes such as brand value or innovation, and exploring causal mechanisms through multi-level modeling or instrumental variable approaches, advanced causal inference methods, such as instrumental variables or difference-in-differences approaches, could further clarify the directionality of the SSCM-performance relationship.

The findings have several practical implications. First, firms seeking immediate financial benefits from SSCM may benefit from prioritizing operationally linked initiatives, such as energy efficiency improvements captured in Scope 2 emissions. Firms could operationalize these findings by developing KPIs linked to Scope 2 energy efficiency, such as electricity consumption per unit of revenue or per production output, and tracking improvements through dedicated sustainability dashboards. Governance reforms can be monitored using metrics like the number of ESG oversight meetings, compliance system coverage, or employee training hours. By linking operational metrics with financial performance indicators, managers can better assess which sustainability initiatives yield short-term gains and which create longer-term strategic value. This approach aligns with the RBV/NRBV perspective, emphasizing that sustainability-related resources and capabilities require measurement and integration into operational routines before their value is fully realized. Second, social and governance practices, while strategically important, yield longer-term or indirect benefits, such as enhanced reputation, stakeholder trust, or regulatory compliance, rather than immediate accounting-based gains. Third, the management of Scope 3 emissions requires greater supply-chain coordination and may provide value primarily through risk mitigation and reputational advantages, emphasizing that not all sustainability initiatives translate directly into short-term profitability.

Adopting a phased implementation strategy allows firms to balance short-term financial performance with longer-term sustainability and resilience objectives. In the initial phase, companies can prioritize operational improvements with relatively quick payoffs, such as energy efficiency measures, waste reduction, and process optimization within their own operations and immediate supply chains. These actions tend to generate cost savings and efficiency gains that can help offset the upfront costs of broader sustainability initiatives. In subsequent phases, firms can gradually expand their focus to more complex social and governance investments, including supplier labor standards, diversity and inclusion initiatives, enhanced transparency, and ESG-linked governance mechanisms. While these investments may not yield immediate financial returns, they strengthen stakeholder trust, reduce regulatory and reputational risks, and improve long-term organizational stability. By sequencing SSCM initiatives in this way, firms can avoid excessive short-term financial strain while building the internal capabilities and external legitimacy needed to sustain performance gains over time.

This study advances the literature on SSCM and corporate financial performance by providing a nuanced, pillar-level and emissions-focused analysis. First, the findings underscore the complexity of translating sustainability initiatives into short-term accounting gains. While RBV and NRBV frameworks suggest that sustainability-related capabilities can confer competitive advantages, our results indicate that the payoff may be delayed or indirect, particularly for social and governance practices. Second, the negative association between governance performance and ROE highlights that initial investments in oversight and compliance mechanisms may temporarily constrain financial outcomes. This suggests that governance benefits manifest more in risk mitigation and long-term resilience than in immediate profitability. Third, the significant positive effect of Scope 2 emissions on financial performance emphasizes that operational efficiency measures can provide tangible short-term benefits, thus complementing the long-term strategic advantages proposed by SSCM theory.

Taken together, these findings reinforce the value of an integrated theoretical approach that combines RBV/NRBV with stakeholder and institutional perspectives. Internal capabilities, external pressures, and contextual factors jointly shape the financial outcomes of sustainability initiatives. Therefore, there may be a need to move beyond aggregated ESG scores to examine dimension-specific and supply-chain-level effects.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations below summarize the main findings of this study in line with the stated research aim, explicitly linking each conclusion to the corresponding research task. They provide both theoretical insights and concrete guidance for practitioners regarding SSCM, ESG performance, GHG emissions, and corporate financial performance.

Task 1: Analyze recent academic and practitioner literature on SSCM, ESG performance, and corporate financial outcomes, and formulate testable hypotheses. The conclusion and recommendations of task 1:

1. SSCM integrates economic, environmental, and social objectives and is explained through RBV, NRBV, stakeholder theory, and institutional theory. Sustainability-related capabilities can confer competitive advantage, but their financial payoff depends on time horizon, implementation depth, and firm context.

1. Practical recommendation: Prioritize operationally-linked SSCM initiatives with measurable short-term benefits, such as energy efficiency improvements, electricity sourcing optimization, and process enhancements reflected in Scope 2 emissions. Theoretical recommendation: Expand sample size and diversity to include more firms across multiple industries and regions to improve statistical power and generalizability of SSCM-financial performance relationships.

Task 2: Design an appropriate quantitative research methodology, including variable operationalization, panel-data structure, and econometric estimation strategy. The conclusion and recommendations of task 2:

2. A longitudinal, firm-level panel design is appropriate for examining SSCM-financial performance relationships, allowing within-firm variation analysis and controlling for time-invariant heterogeneity and year-specific shocks.

2. Practical recommendation: Use panel-data approaches with firm and year fixed effects when assessing SSCM-financial links. Theoretical recommendation: Extend the observation period to capture delayed financial effects of ESG and SSCM initiatives.

Task 3: Compile, harmonize, and preprocess firm-level financial, ESG, and GHG emissions data from Bloomberg for the selected sample. The conclusion and recommendations of task 3:

3. Disaggregated ESG pillar scores (Environmental, Social, Governance) and GHG emissions (Scopes 1, 2, 3) provide richer insights than aggregate ESG scores, as aggregation can mask dimension-specific effects and short-term financial relevance.

3. Practical recommendation: Monitor governance reforms using operational metrics, such as ESG oversight meetings, compliance system coverage, and employee training hours, to

manage short-term resource allocation. Theoretical recommendation: Apply advanced econometric techniques (instrumental variables, difference-in-differences, natural experiments) to address endogeneity and clarify causal mechanisms.

Task 4: Estimate fixed-effects panel regression models assessing the relationship between SSCM indicators and financial performance while controlling for unobserved heterogeneity and time effects. The conclusions and recommendations of task 4:

4. (1) Overall ESG performance does not have statistically significant short-term effects on ROA, ROE, or operating margin, despite positive coefficients. Aggregate ESG scores alone are insufficient to capture short-term financial impacts. (2) Environmental and Social pillar scores are positively but insignificantly associated with financial outcomes, indicating delayed or indirect financial benefits from operational and social sustainability initiatives. (3) Governance pillar performance has a statistically significant negative association with ROE, reflecting short-term costs of governance investments (oversight committees, compliance systems, transparency initiatives). (4) Scope 2 (location-based) emissions are positively and significantly associated with ROA, ROE, and operating margin, suggesting that operationally linked sustainability measures can provide measurable short-term benefits. (5) Scope 1 and Scope 3 emissions do not exhibit statistically significant financial effects, highlighting measurement challenges, multi-tier complexity, and the longer-term nature of upstream supply-chain impacts.

4. Practical recommendation: Enhance Scope 3 emissions data quality and consistency and incorporate intensity-based metrics (per revenue, per assets) to capture operational efficiency better and inform decisions. Theoretical recommendation: Develop models that normalize Scope 3 emissions by firm size or revenue to better capture efficiency effects.

Task 5: Evaluate model diagnostics and robustness checks to ensure the reliability and validity of empirical results. The conclusions and recommendations of task 5:

5. (1) Firm-level heterogeneity is substantial; scatterplots and boxplots illustrate non-linear and dispersed patterns in ESG, emissions, and financial performance. Pooled regressions may mask meaningful effects, reinforcing the need for fixed-effects models and granular analysis. (2) Data limitations, particularly for Scope 3 emissions in recent years, may reduce statistical power and require cautious interpretation. Reliable and consistent reporting is essential for robust SSCM assessment.

5. Practical recommendation: Adopt an integrated KPI system linking sustainability and financial metrics, enabling managers to track which initiatives yield short-term vs. long-term value.

Theoretical recommendation: Normalize emissions metrics and incorporate interactions with firm size, industry, and operational intensity to disentangle scale and efficiency effects.

Task 6: Derive practical recommendations for managers and investors based on the empirical findings. The conclusions and recommendations of task 6:

6. (1) Operational SSCM initiatives, such as energy efficiency and process optimization (Scope 2), yield the most immediate financial relevance and should be prioritized for near-term profitability. (2) Governance and supplier-oriented programs primarily provide long-term strategic value, including risk reduction, compliance, reputational enhancement, and stakeholder trust. Short-term accounting benefits should not be expected. (3) Phased SSCM implementation is recommended: first operational efficiency improvements, then broader social and governance initiatives, and finally supply-chain coordination programs. (4) Combining ESG pillars with GHG emissions across Scopes 1-3 improves decision-making compared to aggregate ESG scores alone, supporting more targeted and actionable SSCM strategies. (5) Context-sensitive and time-aware evaluation of sustainability initiatives is critical; financial benefits often emerge over the medium to long term, requiring integrated KPIs linking operational performance, emissions metrics, and accounting outcomes.

6. Practical recommendation: Focus on long-term benefits of governance and supply-chain investments, recognizing their value in risk reduction, regulatory compliance, and stakeholder trust. Theoretical recommendation: Explore multi-level pathways connecting SSCM initiatives to financial and non-financial outcomes, integrating operational, governance, and stakeholder mechanisms.

In conclusion, this study demonstrates that while SSCM and ESG practices are widely regarded as drivers of long-term competitiveness, their short-term financial effects are neither automatic nor uniform. Aggregate ESG scores alone provide limited explanatory power for immediate profitability, whereas operationally focused sustainability measures show greater short-run relevance. These findings underscore the importance of adopting a strategic, context-sensitive, and time-aware approach to sustainability, both in academic research and in corporate practice.

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ANNEX A – VIF RESULTS OF MODELS 2- 3

Model 2

Variance Inflation Factors
Date: 01/01/26   Time: 19:00
Sample: 2016 2024
Included observations: 82

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	54.87793	542.5450	NA
ENVIRONMENTAL_...	0.226151	52.40949	1.079356
SOCIAL_PILLAR_S...	0.344103	33.13240	1.084708
GOVERNANCE_PIL...	0.871108	459.4252	1.006340

Model 2b

Variance Inflation Factors
Date: 01/01/26   Time: 19:02
Sample: 2016 2024
Included observations: 82

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	2547.527	542.5450	NA
ENVIRONMENTAL_...	10.49830	52.40949	1.079356
SOCIAL_PILLAR_S...	15.97387	33.13240	1.084708
GOVERNANCE_PIL...	40.43833	459.4252	1.006340

Model 2c

Variance Inflation Factors
Date: 01/01/26   Time: 19:07
Sample: 2016 2024
Included observations: 82

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	38.18706	542.5450	NA
ENVIRONMENTAL_...	0.157368	52.40949	1.079356
SOCIAL_PILLAR_S...	0.239446	33.13240	1.084708
GOVERNANCE_PIL...	0.606165	459.4252	1.006340

Model 3

Variance Inflation Factors
Date: 01/01/26   Time: 19:04
Sample: 2016 2024
Included observations: 80

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	6.465839	65.17761	NA
GHG_SCOPE_1	6.84E-07	45.92328	1.441962
GHG_SCOPE_2_L...	1.96E-07	26.60394	1.158284
GHG_SCOPE_3	2.01E-11	6.373723	1.615632

Model 3b

Variance Inflation Factors
Date: 01/01/26   Time: 19:06
Sample: 2016 2024
Included observations: 80

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	338.5765	65.17761	NA
GHG_SCOPE_1	3.58E-05	45.92328	1.441962
GHG_SCOPE_2_L...	1.03E-05	26.60394	1.158284
GHG_SCOPE_3	1.05E-09	6.373723	1.615632

Model 3c

Variance Inflation Factors
Date: 01/01/26   Time: 18:51
Sample: 2016 2024
Included observations: 80

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	4.975346	65.17761	NA
GHG_SCOPE_1	5.26E-07	45.92328	1.441962
GHG_SCOPE_2_L...	1.51E-07	26.60394	1.158284
GHG_SCOPE_3	1.55E-11	6.373723	1.615632