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Supply Chain Network, ESG Scores and Financial Performance

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ABSTRACT

This paper provides novel evidence on the role of supply chain networks in influencing firms' environmental, social and governance (ESG) scores and financial performance. Our analysis employs financial, board, ESG and supply chain data, resulting in an unbalanced panel of over 16,000 firm-year observations from 3028 publicly traded US firms, spanning fiscal years from 2005 to 2021. We use two different supply chain network metrics, namely, the number of supply chain connections (degree centrality) and eigenvector centrality, and we use various financial performance measures such as ROA, ROE, ROS, Tobin's Q and stock returns. Building on resource dependence theory, our results indicate that a larger supply chain network has a positive impact on ESG scores, while there is limited evidence to support a direct relationship between supply chain networks and financial performance. Interestingly, the impact of supply chain networks on financial performance appears to be indirect, operating through ESG, in line with signalling theory. Important practical implications are also discussed.

JEL Classification: G11, G3, Q5

Most of us are not working in supply chain. I don't think they've even thought about the Suez Canal or anything to do with shipping up until that ship got stuck there. Then, all of a sudden, it came to everybody's awareness. To me, it's a blessing in disguise. Supply chain came at the forefront of most discussions, most CEO reports, and so on ...¹

Radu Palamariu, the Managing Director of Asia-Pacific and Europe for Alcott Global, 9 May 2023

cash savings to protect against the propagation of economic shocks through the network (Gao 2020). Importantly, these economic shocks can be inflicted on input producers by the occurrence of natural disasters, which also translate into losses for their customers (Barrot and Sauvagnat 2016). One classic example is the Great East Japan Earthquake of 2011, which caused disruptions that spread upstream and downstream along supply chains, impacting direct and indirect suppliers and customers of affected firms (Carvalho et al. 2020).

More recently, the focus has expanded beyond shareholder value to include a broader range of stakeholders demanding sustainable and resilient operations. This shift has elevated the importance of environmental, social and governance (ESG) performance as a key metric of corporate health and responsibility (Dremptic et al. 2020; Lopez-de Silanes et al. 2024). As investors and stakeholders increasingly prioritise sustainability, understanding the impact of supply chain networks on both ESG and financial performance has become paramount. The existing

1 | Introduction

In today's interconnected global economy, firm networks play a critical role in disseminating corporate strategies and policies (Banerjee et al. 2008), as well as promoting corporate innovation (Capaldo 2007; Chu et al. 2019). For instance, systemically important firms within the production network maintain higher

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literature examines these relationships, but largely in isolation. A substantial body of work demonstrates that strong supply chain networks enhance innovation (Bellamy et al. 2014), promote transparency (Gualandris et al. 2021), reduce information asymmetry (Dahlmann and Roehrich 2019) and contribute to higher productivity through collaboration and knowledge transfer (Serpa and Krishnan 2018). Therefore, supply chain management is closely linked to financial performance, with effective strategies leading to revenue growth, cost efficiency and improved profitability (see e.g., Z. Wang and Sarkis 2013).

In parallel, ESG scores serve as key indicators of corporate sustainability, influencing investor decisions and long-term economic value (Galbreath 2013; Barman 2018; Clément et al. 2023). Furthermore, sustainable supply chain management has been shown to improve ESG performance by reducing environmental impact, promoting social equity and strengthening governance (Tamayo-Torres et al. 2019; Koberg and Longoni 2019; Tiwari et al. 2023; Das 2024). However, a comprehensive analysis of how the structure of a firm's supply chain network influences its ESG scores and, consequently, its financial outcomes remains underexplored. Our research aims to bridge this gap by investigating whether a firm's position within the supply chain network directly improves its ESG performance and indirectly boosts its financial performance, thereby shedding new light on value creation in modern business ecosystems.

From a theoretical point of view, resource dependence theory (RDT), (see, for instance, Pfeffer and Salancik 1978) explains how supply chain structures shape corporate ESG and financial outcomes. RDT views firms as interdependent entities that seek to manage external resource dependencies. To reduce the risk of supply chain disruptions, gain access to cleaner technologies and strengthen operational resilience, firms aim to expand and stabilise their supply chain relationships. Firms with an extended supply chain network gain advantages from faster diffusion of sustainable practices, stronger reputational capital and closer stakeholder scrutiny, all of which reinforce ESG and financial performance metrics. However, this position within the supply chain can be a 'double-edged sword', as it exposes firms to significant market and nonmarket pressures. To explain this, we extend our framework by incorporating signalling theory (Spence 1973). This theory sheds light on the mechanisms through which market participants convey information. It posits that in markets characterised by information asymmetry, ESG performance acts as a signal of a firm's underlying quality and managerial competence to investors.

Informed by these theoretical perspectives, we seek to answer the following questions: (1) Does a central position within a supply chain network lead to improved ESG performance? (2) Is there a direct relationship between supply chain network structure and corporate financial performance? (3) Does ESG performance serve as a mechanism through which supply chain networks indirectly influence financial performance?

With these considerations in mind, the aim of our paper is to investigate the impact of supply chain network on both ESG and financial performance among US firms over the period from January 2005 to December 2021. We seek to extend the limited literature by focusing on two specific network measures:

eigenvector centrality, which measures the relative importance of a firm within the supply chain network, and a more straightforward measure—the number of supply chain connections (degree centrality) per firm. Unlike simple degree-based measures, eigenvector centrality represents not only the number of direct connections a firm has but also the importance of those connections, reflecting proximity to other highly central firms (see, for example, Bonacich 2007; Bienenstock and Bonacich 2022). Put differently, a firm occupies a central position in the supply chain if it is connected to other firms that themselves possess high levels of connectivity within the network.

Our study makes several key contributions to the literature. First, and foremost, we jointly model supply chain networks, ESG and financial performance. While previous studies such as Hao et al. (2025) have examined how international supply chain relationships improve corporate ESG performance through customer signalling, and Xu et al. (2025), Luo et al. (2023) and Serpa and Krishnan (2018) have linked supply chain network structures to financial performance, these streams of literature have evolved largely in parallel. Similarly, Le Tran and Coqueret (2023) document the propagation of ESG shocks through supply chain relationships, showing that such shocks affect the stock returns of suppliers and customers. We bridge this gap by explicitly testing the indirect channel through which supply chain networks affect financial performance via ESG mechanisms, thereby unifying insights from the ESG-finance literature with network-based supply chain research. This addresses a key ambiguity in prior research by demonstrating that the financial benefits of an extensive supply chain are not merely direct but are significantly transmitted through enhanced sustainability performance. This highlights the interconnectedness of firms and establishes ESG as a critical mechanism that links strategic supply chain design to financial outcomes.

Second, unlike previous studies, such as Basole et al. (2017), which focused on a single industry, our research offers novel methodological contributions by employing robust, node-based network measures (e.g., eigenvector centrality) across a comprehensive sample of eleven distinct industries—energy, materials, industrials, consumer discretionary, consumer staples, health care, financials, information technology, communication services, utilities and real estate. This multi-industry approach enables us to demonstrate that the proposed relationships remain consistent across diverse economic sectors, thereby enhancing the robustness of our findings.

Finally, our results provide practical implications. We offer clear insights for managers who seek to leverage their supply chain for competitive advantage and resilience, for investors who evaluate firm sustainability and long-term risk and for policymakers who aim to design effective incentives for sustainable economic practices.

Our findings indicate that an extensive supply chain network, whether measured by the number of supply chain connections (degree centrality) or eigenvector centrality, has a positive and significant impact on firms' ESG performance. In particular, when ESG scores are disaggregated into their ESG pillars, we observe that the environmental pillar exhibits the strongest response to the expansion of a supply chain network. This disaggregation of

ESG scores provides a clearer picture and a deeper understanding of the relationship between supply chain networks and the ESG performance of firms. However, our analysis does not establish a direct relationship between supply chain networks and financial performance in all financial metrics examined. While a positive and significant effect is observed for return on sales (ROS), other financial variables remain largely unaffected. Nonetheless, our results indicate that supply chain networks exert an indirect influence on financial performance through their impact on ESG performance. Overall, our main findings are consistent with the principles of RDT and signalling theory.

The rest of this study is structured as follows. Section 2 provides a brief review of the literature and formulates the hypotheses. Section 3 describes the data, sample, variables and methodology. Section 4 presents the empirical findings and discussion. Section 5 outlines robustness checks. Section 6 concludes.

2 | Literature Review and Testable Hypotheses

A supply chain is the end-to-end process of creating and delivering a product or service, which encompasses the sourcing of raw materials, production, distribution and final delivery to customers.² By nature, supply chains embed firms within complex production networks where shocks, resources and practices propagate. Within this context, ESG scores have emerged as key indicators of corporate sustainability performance and broader societal impact, increasingly used by investors, regulators and other stakeholders to evaluate corporate health and long-term value. At the same time, financial performance, measured by profitability, growth and market valuation, remains the primary benchmark for corporate success.

This section reviews key studies at the intersection of supply chain networks, ESG scores and financial performance and positions our hypotheses. We begin by considering evidence on how supply chain networks shape ESG practices (Section 2.1). We then turn to the link between supply chain networks and financial performance (Section 2.2). Finally, we discuss the theoretical foundations that motivate our testable hypotheses, which integrate insights from the existing literature (Section 2.3).

2.1 | Supply Chain Network and ESG Performance

In today's interconnected economy, a firm's ESG performance is increasingly shaped by the actions and standards of its supply chain partners. Consequently, the structure and management of supply chain networks have emerged as critical determinants of corporate sustainability. A growing body of research substantiates this link, highlighting how sustainable supply chain practices are anticipated to improve a firm's ESG performance (Koberg and Longoni 2019).

Empirical evidence consistently affirms this positive relationship. Studies on US and European firms by Tamayo-Torres et al. (2019) and on global multinationals by Das (2024) demonstrate that proactive supply chain management and sustainability initiatives lead to significant ESG improvements. This relationship holds in different contexts, and research on Chinese

companies shows that greater supply chain connectivity (Hao et al. 2025) and optimised management (Qiao et al. 2025) enhance ESG ratings. By contrast, Jia et al. (2025) find a U-shaped relationship for Chinese manufacturers, which suggests that both highly concentrated and highly diversified supply chains can be associated with stronger sustainability performance, whereas a middle ground may be less effective. This notwithstanding, the connection is sufficiently important that shareholders are increasingly pressing companies to adopt sustainable supply chain practices (Truant et al. 2024), and firms with sophisticated supply chain strategies tend to exhibit higher ESG scores (Q. Wang et al. 2024).

The significance of these findings is amplified by the established materiality of ESG performance itself. Robust ESG credentials are increasingly viewed as a component of competitive strategy (Galbreath 2013) and a source of long-term economic value (Barman 2018). Investors use ESG scores to identify risks and opportunities (Drempetic et al. 2020), which influence institutional ownership (Lopez-de Silanes et al. 2024) and can lead to lower market risk (Tzouvanas and Mamatzakis 2021). The scores are widely used to evaluate corporate sustainability and social responsibility (Clément et al. 2023).

2.2 | Supply Chain Network and Financial Performance

Beyond their influence on sustainability profiles, supply chain networks are fundamental drivers of operational efficiency, innovation and, consequently, financial performance. A well-structured network facilitates the flow of not only goods but also information and knowledge, which directly translates into competitive advantages and superior financial outcomes.

A substantial body of literature establishes that a firm's position within supply chain networks is a critical determinant of its performance and resilience, which functions as a central channel for the propagation of shocks, resources and competitive advantages. The economics literature highlights the role of networks in transmitting risk, showing that supplier-specific shocks propagate to customers (Barrot and Sauvagnat 2016) and that major disruptions cascade upstream and downstream (Carvalho et al. 2020). Complementing this, finance research demonstrates that interfirm networks shape outcomes through intangible channels like trust, reputation and access to capital (Giannetti et al. 2021; Franzoni et al. 2023; Ersahin et al. 2024a, 2024b).

A firm's specific position within this structure can be quantified to capture different dimensions of influence. While simple degree measures (e.g., the number of supply chain connections) reflect the breadth of connections, eigenvector centrality provides a more nuanced measure by weighting a firm's connections by the importance of its partners (Bonacich 2007; Bienenstock and Bonacich 2022). A central position thus confers both privileged access to resources and heightened exposure to systemic shocks.

A primary mechanism through which central firms capture value is by achieving superior operational efficiency and innovation. A well-structured network facilitates the flow of information and knowledge, which directly enhances innovative

output (Bellamy et al. 2014) and firm productivity through collaboration and knowledge transfer (Serpa and Krishnan 2018). Furthermore, network density is associated with greater transparency (Gualandris et al. 2021) and helps firms reduce uncertainty and information asymmetry (Dahlmann and Roehrich 2019).

These operational and innovative advantages provide a clear pathway to enhanced financial performance. Early empirical work by Dehning et al. (2007) established that improvements in supply chain management systems directly increase profitability metrics such as gross margin, inventory turnover and ROS. The strategic importance of network configuration is highlighted by Wagner et al. (2012), who find that a strong 'fit' between a firm and its supply chain leads to higher return on assets (ROA). This relationship holds even when considering sustainability, as Z. Wang and Sarkis (2013) show that sustainable supply chain management is positively associated with ROA and return on equity (ROE).

The financial benefits also stem from the power dynamics and risk mitigation inherent in network structures. Research by Kim and Henderson (2015) indicates that a supplier's dependency on a focal firm strengthens the firm's financial performance in terms of ROA and ROS. Similarly, Basole et al. (2017) document that the density of a firm's supply network has a positive effect on performance, measured by ROA and key efficiency ratios. The financial impact is also evident in risk management; H. L. Chen (2018) finds that risks originating from the supply chain network significantly affect corporate financial performance, which underscores the cost of poor network management. Finally, the value creation extends to the stock market, with Luo et al. (2023) concluding that network structures are significantly related to firms' stock returns.

Overall, the literature delineates a clear causal chain: the structure and management of a firm's supply chain network stimulate operational efficiency, innovation and transparency. These operational advantages, in turn, manifest as reduced costs, higher sales and improved risk profiles, which are directly captured in superior financial performance. This established direct pathway sets the stage for our study's central investigation into the indirect financial value created through enhanced ESG performance.

2.3 | Theoretical Background and the Testable Hypotheses

In recent years, there has been a growing interest in the literature that examines the relationship between supply chain networks and ESG scores. This trend is driven in part by the greater acceptance of ESG scores as recognised indicators for companies to measure their sustainability performance. In addition to this, the growing attempts in the literature can be linked to the increasing availability of data and the requirement for firms to report ESG information.³

Theoretically, we build upon the RDT, developed by Pfeffer and Salancik (1978). The theory helps to explain the relationship among supply chain networks, ESG scores and financial

performance. It focuses on how firms manage their dependencies on external resources to reduce uncertainty and gain competitive advantages. For example, firms that strengthen their supply chain networks can mitigate dependency risks, ensure operational continuity, negotiate more favourable terms and therefore improve financial performance. Additionally, firms that integrate sustainable supply chain practices or have access to diverse suppliers (e.g., reducing their carbon footprint) can improve their ESG scores by selecting resources that enhance their ESG practices.

In greater detail, a larger supply chain network is expected to improve practices such as communication and collaboration between a focal firm and its suppliers and to further enhance the focal firm's reputation and innovation. Furthermore, it helps to avoid overdependence on a smaller number of suppliers. In this regard, Bellamy et al. (2020) argue that the structural position of the firm in relation to its supply network reflects information flows, network learning and status. Such developments reduce firms' environmental waste, information asymmetry with employees and corrupt practices in the managerial team. To this end, Gualandris et al. (2021) report that supply chain density is positively associated with supply chain transparency in the context of collective ESG disclosures made by customers and suppliers of a focal firm. Therefore, we argue that the strategic management of external dependencies through an extensive supply chain network is a primary driver of improved ESG performance.

Empirical studies lend consistent support to our first hypothesis by linking sustainable supply chain management to improved ESG performance (Koberg and Longoni 2019; Das 2024), which supports the premise that network size and centrality are enablers of such sustainability initiatives. The environmental pillar is expected to be particularly responsive due to the direct impact of supply chain operations on issues like carbon emissions and waste (Dahlmann and Roehrich 2019).

H1: *A larger supply chain network has a positive impact on firms' ESG performance.*

The second hypothesis posits that supply chain networks directly influence corporate financial performance through operational efficiencies, strategic alignment and risk mitigation, independent of ESG considerations. Beyond serving as operational infrastructure, supply chain networks constitute economically meaningful inter-firm linkages that increasingly influence firm valuation and stock returns (Breitung and Müller 2025).⁴ The theoretical foundation for this direct relationship is grounded in RDT, which posits that firms derive competitive advantage by effectively managing external dependencies (Pfeffer and Salancik 1978). Well-connected firms can leverage bargaining power to negotiate favourable procurement terms, access critical inputs and mitigate supply disruptions, all of which may translate into stronger profitability.

Consistent with this perspective, evidence indicates that buyer-supplier dependencies influence corporate financial policies and materially affect firm value, which underscores the economic significance of supply chain relationships (Banerjee et al. 2008). Operational mechanisms further support this link. Productivity spillovers propagate through

vertical supply chain relationships, which allow firms to benefit from interactions with more productive partners (Serpa and Krishnan 2018). Such spillovers enhance operational efficiency and asset utilisation. This implies that network position can directly affect firm-level performance.

Additionally, a larger supply chain network is anticipated to provide reliability and flexibility in sourcing and delivery, which translates into timely and cost-effective product availability (Giannetti et al. 2021). These improvements support revenue growth, market share expansion and cost reductions in inventory and production. Network structure has also been shown to provide competitive advantage and facilitate risk distribution, resulting in improved firms' ability to respond to market and supply uncertainties (Basole et al. 2017; Ersahin et al. 2024a).

More broadly, the supply chain management literature documents positive associations between effective supply chain practices and both accounting- and market-based financial performance (Shi and Yu 2013). Strategic supply chain integration and relational alignment are shown to enhance profitability and shareholder value. Such network configurations also shape firms' exposure to operational shocks. Idiosyncratic supplier disruptions propagate through production networks, particularly when inputs are specific and difficult to substitute (Barrot and Sauvagnat 2016). While this highlights downside risk, it also implies that well-developed and diversified networks enhance resilience and stabilise operating performance. Consistent with this view, sustainable supply chain engagement has been shown to improve accounting returns such as ROA and ROE (Z. Wang and Sarkis 2013).

Taken together, theoretical reasoning, primarily grounded in RDT, and empirical evidence suggest that supply chain networks function as strategic economic systems that enhance operational efficiency, mitigate risk and strengthen profitability. Firms that occupy larger and more central positions within these networks are therefore expected to realise superior financial performance.

H2: *A larger supply chain network has a positive impact on firms' financial performance.*

It is worth noting that, according to RDT, firms operate within a network of interdependent relationships that provide access to critical resources, information and capabilities necessary for competitive advantage (Pfeffer and Salancik 1978). However, this interdependence also exposes firms to the behaviour and reputation of their supply chain partners. Therefore, a larger supply chain network entails both opportunities for resource exchange and risks associated with increased interconnectivity and visibility. The ability to manage these dependencies effectively becomes crucial, particularly as ESG considerations have become central to assessing corporate legitimacy and long-term sustainability. Findings by Le Tran and Coqueret (2023) provide strong support for this view. Their examination of US firms and their global supply chain partners demonstrates that ESG-related news is rapidly incorporated into stock prices, which affects not only the directly involved companies but also their upstream and downstream partners.

Furthermore, Le Tran and Coqueret (2023) show that ESG-related news not only influences the valuation of the focal firm but also transmits through its supply chain, which affects suppliers and customers alike. This evidence highlights the systemic nature of ESG performance: Firms are not isolated entities but nodes in a broader network where sustainability practices and reputational effects are interlinked. Larger networks amplify this dynamic, both by increasing exposure to ESG shocks and by improving firms' capacity to coordinate sustainability standards and diffuse best practices across their partners.

From a signalling theory perspective (Spence 1973), strong ESG performance conveys a market signal of superior management quality, strategic foresight and lower exposure to nonfinancial risks. Such signals alleviate information asymmetries between firms and external stakeholders, particularly investors, thereby enhancing trust, attracting sustainable capital and potentially reducing the cost of financing (Ariefianto et al. 2025). Within extensive supply chain networks, this signalling effect is magnified: Firms with stronger ESG reputations can leverage their networks to reinforce legitimacy and market confidence, which ultimately supports superior financial outcomes.

Taken together, these insights inform our third hypothesis which posits that the financial benefits of supply chain networks are not purely direct but are influenced through the enhancement of ESG performance. Larger networks can amplify ESG-driven signalling effects, which boosts investor confidence and improves market valuation. Therefore, the link between network size and financial performance operates primarily through the ESG channel, which reflects both reputational interdependence and strategic coordination across interconnected firms.

H3: *A larger supply chain network has an indirect effect (via ESG) on financial performance.*

3 | Research Design

3.1 | Data Sources

The period of analysis spans from January 2005 to December 2021. In line with the literature, we use the LSEG Workspace to collect data on ESG scores. Financial variables are sourced from the Compustat database, with the exception of Institutional Ownership, which is retrieved from LSEG. Additionally, board-level characteristics such as directors' gender, nationality, education, experience, board size and director networks are collected from the BoardEX database.

There are several ESG rating providers, and prior studies document substantial disagreement across their ratings (see, for example, Gibson Brandon et al. 2021; Berg et al. 2022; Christensen et al. 2022). In particular, Christensen et al. (2022) show that firms with higher levels of ESG disclosure tend to exhibit greater rating divergence across providers. For example, LSEG relies exclusively on publicly available information, whereas S&P Global additionally collects data through firm surveys. Both providers report ESG scores on a 0–100 scale. However, in April 2020, Refinitiv (currently LSEG) revised its ESG methodology, leading

TABLE 1 | Sample composition.

Year	N. of Obs	Cum. N. of firms	Per cent
2005	288	288	1.78
2006	305	324	1.88
2007	337	373	2.08
2008	425	499	2.63
2009	450	571	2.78
2010	489	628	3.02
2011	499	666	3.08
2012	498	690	3.08
2013	544	726	3.36
2014	558	760	3.45
2015	934	1147	5.77
2016	1338	1639	8.27
2017	1640	2041	10.13
2018	1760	2260	10.87
2019	1950	2547	12.05
2020	2089	2827	12.91
2021	2080	3028	12.85
GICS sector	N. of Obs	N. of firms	Per cent
10. Energy	1053	179	6.51
15. Materials	1105	148	6.83
20. Industrials	2774	434	17.14
25. Consumer Discretionary	2077	360	12.83
30. Consumer Staples	810	123	5
35. Health Care	2029	545	12.54
40. Financials	2229	487	13.77
45. Information Technology	2052	398	12.68
50. Communication Services	624	112	3.86
55. Utilities	697	82	4.31
60. Real Estate	734	160	4.54
Total	16,184	3028	100

Note: This table shows the sample composition by (a) year and (b) sector. The sector classification is based on Global Industry Classification Standard (GICS).

to abrupt changes in firms' scores. Kiesel and Schnitzler (2024) find that firms negatively affected by this revision subsequently improved not only their overall ESG scores but also their ESG sub-scores, with similar improvements observed in ESG ratings from S&P Global.

Next, for the measures of eigenvector centrality and the number of supply chain connections (degree centrality), measured as the natural logarithm of the number of nodes, LN(NODES), we employ data from Frésard et al. (2020), who developed a dataset that captures pairwise vertical relatedness among US firms. This dataset includes the top 10% of firm pairs with the highest potential for vertical relatedness, covering the period from 1991 to 2021. It comprises over 80 million pairwise connections.

Our initial board membership sample comprised approximately one million director-year observations, representing around 40,000 individual directors across 13,000 firms globally. Upon filtering for firms with available corporate, financial and supply chain data, our final sample consists of 3028 US firms.

Table 1 shows the composition of our sample by sector and year, based on the Global Industry Classification Standard (GICS) framework. As shown, the sample is diverse, covering a range of industries. The list of variables employed in the analysis, along with their definitions and data sources, is reported in Table 2.

3.2 | Dependent Variables: ESG and Financial Performance

We begin by outlining the ESG scores. These scores are based on a comprehensive rating system, which covers over 10,000 companies, with values ranging from 0 to 100, where higher scores signify better ESG performance. Our sample is classified into three main pillars and 10 specific categories: (i) environmental (resource use, innovation and emissions), (ii) social (workforce, human rights, community engagement and product responsibility) and (iii) governance (management quality, shareholder rights and corporate social responsibility strategy). The use of these ESG scores is consistent with the established literature in the field (see, for example, Das 2024).

In terms of financial performance, we adopt a range of widely used measures, following the literature. First, ROA, calculated as net income divided by total assets, measures firm profitability in relation to its asset base (see Wagner et al. 2012). Second, ROE, defined as net income divided by shareholders' equity, measures firm profitability in relation to equity value (see Z. Wang and Sarkis 2013). Third, ROS, the ratio of EBIT to sales, reflects firm operating efficiency (see Kim and Henderson 2015). Fourth, Tobin's Q is calculated as (market value of equity + book value of liabilities)/(book value of equity + book value of liabilities). It is a proxy for market valuation relative to book value (see Tamayo-Torres et al. 2019). Finally, stock returns are measured as the natural logarithmic change in the stock price from year $t - 1$ to t (see Luo et al. 2023).

3.3 | Independent Variables: Supply Chain Network

The existing literature offers various approaches to measuring supply chain network structures. For example, Bellamy

TABLE 2 | Variable definitions.

Variables	Definitions	Source
Panel A: Main variables		
ESG	ESG score is the weighted average score by the three pillars (E, S and G).	LSEG
E	Environmental score is the weighted average of resource use, emissions and innovation scores.	LSEG
S	Social score is the weighted average of workforce, human rights, community and product responsibility scores.	LSEG
G	Governance score is the weighted average of management quality, shareholders' rights and the company's corporate social responsibility strategy scores.	LSEG
EIGEN	Supply chain eigenvector centrality calculated as shown in Equation (2). We use the Pairwise Vertical Relatedness Network data: Basic 10% Granularity Version.	Fresard–Hoberg–Phillips Vertical Relatedness Data Library
LN(NODES)	The natural logarithm of supply chain connections as shown in Equation (1). We use the Pairwise Vertical Relatedness Network data: Basic 10% Granularity Version.	Fresard–Hoberg–Phillips Vertical Relatedness Data Library
Panel B: Board variables		
GENDER	Percentage of female directors in the firm's board for any year given.	BoardEX
NATION	Percentage of firm's board members who are not Americans for any year given.	BoardEX
EDUC	Percentage of board members with either PhD or MBA in the board.	BoardEX
EXP	Average years of work experience in a board.	BoardEX
NETWORK	Number of board members sitting in outside boards.	BoardEX
BSIZE	Number of directors sitting on the firm's board.	BoardEX
Panel C: Financial variables		
TOBINQ	This variable is calculated as (equity market value + liabilities book value)/(equity book value + liabilities book value). It measures market value of the company's equity capital.	Compustat
IOWNER	Percentage of institutional owners for any year given.	LSEG
LN(TA)	The size of the firm is proxied by the natural logarithm of firm's total assets.	Compustat
INEF	Inefficiency is calculated as the ratio of total cost of goods to total sales.	Compustat
LIQUID	Liquidity is calculated as the ratio of current assets to current liability. It measures the company's liquidity ratio.	Compustat
LEV	Leverage is the total debt to total equity of the firm. It is a proxy for firm risk.	Compustat
RETURN	The stock return is measured as the logarithmic difference between the price of a stock at year t to $t - 1$.	Compustat
ROA	Return on assets is the ratio of net income to total assets. It shows firm profitability in relation to total assets.	Compustat

(Continues)

TABLE 2 | (Continued)

Variables	Definitions	Source
ROE	Return on equity is the ratio of net income to shareholders' equity. It shows firm profitability in relation to equity value.	Compustat
ROS	Return on sales is the ratio of EBIT to sales. It shows operating efficiency.	Compustat

Note: The table describes the variables we use in our empirical analysis. The first column ('Variables') labels each variable. The second column 'Definitions' describes each variable and explains how it is defined/computed/measured. The third column 'Source' acknowledges the source of information.

et al. (2014) employ information centrality to assess supply network accessibility, while Basole et al. (2017) employ eigenvector centrality and ego network density. More recently, Luo et al. (2023) adopt metrics such as degree centrality, PageRank centrality, clustering coefficients and measures of structural holes. In this study, we focus on two explanatory variables to capture firms' supply chain network characteristics: the number of supply chain connections (degree centrality) and eigenvector centrality. The number of supply chain connections (degree centrality) represents the total number of direct supplier and customer relationships of a focal firm within the supply chain network. Eigenvector centrality, on the other hand, measures the transitive influence of a firm (node) within the network, based not only on the number of connections it has but also on the importance of the firms to which it is connected. To assess the relative importance of each customer or supplier, we examine their contribution to the broader networked economy. From a supplier matrix A , a simple degree centrality vector, **Nodes**, can be calculated as the sum of each row:

$$\mathbf{Nodes} = A\mathbf{e}, \quad (1)$$

where $\mathbf{e}$ denotes a vector of ones. Although informative, degree centrality is a basic measure that does not account for the quality or influence of connections. To address this limitation, we utilise eigenvector centrality, originally developed by Bonacich (1972). Eigenvector centrality is frequently used in financial research, including studies that centre on CEO and supply chain networks (El-Khatib et al. 2015; Wu 2015; Conti and Graham 2020; Ding et al. 2025). The essence of this measure is that a firm's influence increases if it is connected to other influential firms. Thus, a customer that is itself a significant supplier to many firms carries a greater weight in the supply chain network. In contrast to merely summing a supplier's connections, eigenvector centrality assigns a weighted score to each supplier based on the centrality of its customers. Let $c_{i,t}$ represent the centrality score of supplier i at time t , j be the customer, and $w_{i,j,t}$ denote the weight of vertical relatedness between the supplier i and customer j . Then, the eigenvector centrality of firm i is:

$$c_{i,t} = \frac{1}{\lambda_t} \sum_j w_{i,j,t} A_{i,j,t} c_{j,t}, \quad (2)$$

where λ_t denotes the largest eigenvalue of the weighted supplier matrix. The eigenvector centrality captures the dual influence of the quantity and quality of a firm's connections: Centrality increases if a firm has many customers, influential customers or both. To ensure comparability across years, we normalise the centrality scores such that $\mathbf{e}^T \mathbf{c} = N$, where N is the total number of firms in the network. With this normalisation, the

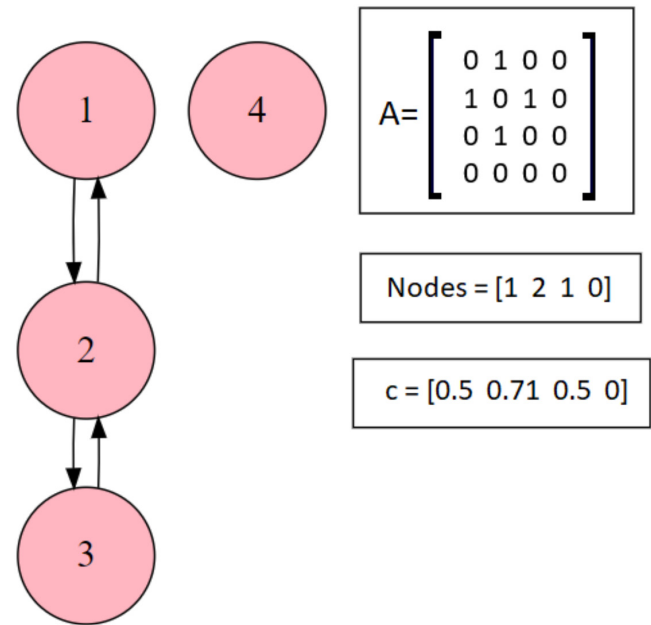


FIGURE 1 | Illustration of a hypothetical network. Note: This figure shows a hypothetical supply chain network that includes four firms. Firm 2 is central, while Firm 4 is isolated. A is the adjacency matrix, Nodes show the number of supply chain connections (degree centrality) and c is the eigenvector centrality measure for each firm.

average centrality does not vary with the size of the economy for a given year.

Figure 1 displays a hypothetical example of how a network of four firms can be represented. Firm 2 is central in this network with two direct connections (nodes) and an eigenvector score of 0.71. Firms 1 and 3 have identical connections and thus have the same nodes and eigenvector centrality, while Firm 4 is isolated with 0 nodes and 0 eigenvector.

Figure 2 displays two supply chain network measures, namely the number of supply chain connections (degree centrality) (on the left-hand side) and eigenvector centrality (on the right-hand side) across different sectors. As expected, materials, industrials and utilities companies have a more extended supply chain network compared with financials and health care companies. This may be related to the fact that materials, industrials and utilities companies rely on multiple suppliers, and thus they operate in a more complex environment. For instance, the utilities sector includes renewable energy companies that need to persistently improve their technologies and establish more energy-efficient processes to deliver on customer expectations.

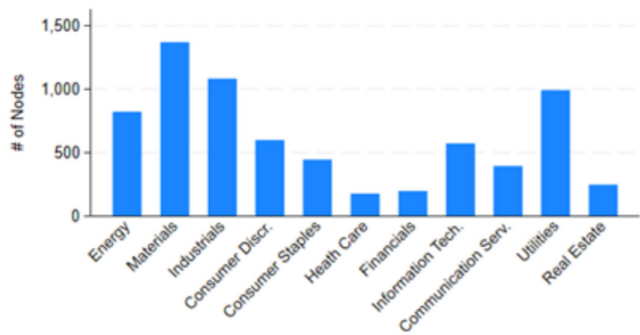


FIGURE 2 | Supply chain network per sector.

3.4 | Econometric Model

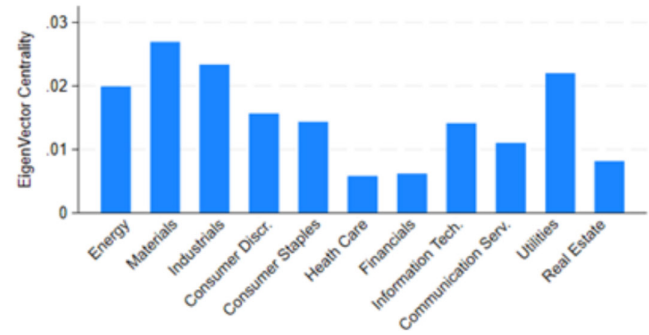
In terms of identification of the impact of supply chain network on firm performance (either ESG scores or financial performance), we opt for a panel data model that considers heterogeneity across firms, years and sectors. Equation (3) outlines the model below:

$$Y_{i,t} = \alpha_0 + \alpha_1 \text{Supply}_{i,t-1} + \alpha_2' \text{Board}_{i,t-1} + \alpha_3' \text{Financial}_{i,t-1} + \alpha_4' \text{Year}_t + \alpha_5' \text{Year}_t \times \text{Sector}_j + u_{i,t}, \quad (3)$$

In Equation (3), the dependent variable, $Y_{i,t}$, represents either the ESG scores (also decomposed into the ESG pillars) or financial performance (ROA, ROE, ROS, Tobin's Q and stock returns) for firm i at time (year) t , where $i = 1, 2, \dots, N$, $t = 2005, 2006, \dots, 2021$, and $u_{i,t}$ is the random disturbance term. All explanatory variables are lagged by 1 year to mitigate possible reverse causality and simultaneity concerns. We also allow for the possibility that firms' performance responds with a lag.

The key explanatory variable, *Supply*, measures the supply chain network (either LN(NODES) which is the number of supply chain connections [degree centrality] or eigenvector centrality). Next, we employ a set of financial control variables ($\text{Financial}_{i,t-1}$), including LN(TA), institutional ownership, inefficiency, liquidity, leverage and Tobin's Q. Finally, we employ a set of board-level variables ($\text{Board}_{i,t-1}$), such as gender, foreign directors, education, experience, network of directors and board size.⁵

We also control for firm fixed effects. The use of year fixed effects allows us to account for an unobserved time variation in the data that is not already captured by the time-varying covariates. The $\text{Year} \times \text{Sector}$ fixed effects control for time-varying, industry-specific shocks, such as regulation, technological change or stakeholder pressure, that affect ESG performance, in line with Bisetti et al. (2026). In this regard, pursuant to institutional theory, organisations operating in the same industry and facing similar institutional pressures converge towards similar norms in terms of sustainable development through coercive, mimetic and normative processes (DiMaggio and Powell 1983; Escobar and Vredenburg 2011). Specifically, normative isomorphism suggests that product certifications, as



well as professional accreditations, conventions and standards, evolve into organisational norms at the sector level (DiMaggio and Powell 1983). The estimated coefficient standard errors are robust to autocorrelation and heteroscedasticity.

In addition, Table 3 shows the descriptive statistics of the firms in our sample. Turning our attention to the mean values, the mean of LN(NODES) is around 5.2, which indicates that firms have, on average, around 180 important supply chain connections with the maximum number being 3760 connections. Similarly, firm size, measured by LN(TA), has a mean value of around 8.1, implying that firms have average total assets of approximately \$3.4 billion, with the maximum size reaching \$3.3 trillion. In terms of the standard deviation, minimum and maximum values, the environmental component of ESG scores appears more volatile compared with the social and governance components. This may possibly be attributed to the fact that firms have to address a wide range of issues related to the environmental pillar, such as carbon emissions, energy and water resources, waste and renewable energy sources. In the same line of reasoning, ROS appears more volatile compared with ROA and ROE. This may reflect the pricing policies of the firms in our sample, which affect sales revenues more directly than assets and equity.

4 | Empirical Results and Discussion

4.1 | The Relationship Between Supply Chain Network and ESG Scores

Table 4 summarises the results on the impact of a large supply chain network (measured by either eigenvector centrality or the number of supply chain connections (degree centrality)) on ESG scores, both collectively and individually (ESG components). The findings in Columns 1 and 5 provide evidence that a large supply chain network indeed has a positive and highly significant impact on ESG scores collectively. Similarly, our findings in Columns 2 and 6 further indicate that a large supply chain network influences the environmental pillar. Once again, this effect appears positive and highly significant. Moreover, our results differ when we focus on the social pillar, as we are unable to find a significant relationship, while the effect on the governance pillar is moderately significant for the number of supply chain connections (degree centrality) as a proxy for the supply chain network. Overall, our results are consistent with our first

TABLE 3 | Descriptive statistics.

Variable	Obs	Mean	Median	St.Dev	Min	Max	Skew	Kurt
ESG	16,184	40.627	37.223	19.248	0.44	95.162	0.491	2.401
E	16,108	26.564	18.282	27.423	0	98.546	0.756	2.31
S	15,129	42.685	39.461	20.964	0.629	98.011	0.437	2.393
G	14,725	49.018	49.522	22.107	0.166	99.441	−0.046	2.083
EIGEN	16,184	0.015	0.014	0.012	0	0.037	0.249	1.62
LN(NODES)	16,184	5.257	5.916	2.106	0	8.232	−0.88	2.765
GENDER	16,184	0.218	0.143	0.26	0	1	1.431	4.622
NATION	16,184	0.499	0.5	0.357	0	1	0.04	1.672
EDUC	16,184	0.267	0.2	0.277	0	1	1.055	3.436
EXP	16,184	3.969	3.271	3.222	0	38.5	2.379	14.861
NETWORK	16,184	3.355	2	3.856	0	51	2.767	19.345
BSIZE	16,184	12.196	10	9.695	1	108	1.799	9.678
TOBINQ	15,451	1.427	1.001	1.236	0.238	7.422	2.725	11.5
IOWNER	16,184	0.801	0.865	0.216	0	1	−1.47	4.862
LN(TA)	16,099	8.128	8.114	1.832	0.44	15.136	0.055	3.413
INEF	13,821	0.89	0.632	2.408	0	27.194	9.515	98.426
LIQUID	13,634	0.35	0.253	0.424	0	6.514	7.129	85.07
LEV	15,451	1.479	0.561	2.691	0.001	22.761	4.162	25.553
RETURN	14,737	0.057	0.087	0.431	−1.853	1.585	−0.403	5.843
ROA	14,107	0.268	0.246	0.235	−0.959	1.023	0.012	5.93
ROE	13,989	0.293	0.21	0.363	−1.483	2.534	3.028	18.352
ROS	16,098	0.748	0.603	0.657	0	3.344	1.507	5.747

hypothesis regarding the positive impact of a large supply chain network on ESG scores collectively. However, this impact, although positive, does not appear to be consistently significant when we disaggregate ESG scores into their ESG pillars as previously mentioned.

We note that the coefficients of EIGEN appear large in magnitude. This is expected because eigenvector centrality is measured on a small scale in our sample, which ranges between 0 and 0.037, with a standard deviation of 0.012, as shown in Table 3. Accordingly, even moderate changes in eigenvector centrality correspond to substantial shifts in a firm's relative influence within the supply chain network, which reflects stronger connections to influential (highly connected) partners. To assess economic significance, we translate the estimates into the effect of a one-standard-deviation increase in eigenvector centrality. The results, reported in Table A1, indicate that a one-standard-deviation increase in eigenvector centrality (0.012) is associated with an increase of approximately 0.60 points in the overall ESG score and about 1.50 points in the Environmental pillar (see Columns 1 and 2). Similarly, a one-standard-deviation increase in the number of supply chain connections (2.106) is associated with an increase of approximately 0.55 points in the overall ESG score and about 1.11 points in the environmental

score (see Columns 5 and 6). When effects are standardised, eigenvector centrality exhibits a somewhat stronger economic association with ESG outcomes than network size does. The difference is relatively small for the overall ESG score but more noticeable for the environmental score. This pattern suggests that a firm's structural position within the network may be particularly relevant for environmental sustainability outcomes, beyond the mere size of the supply chain network.

A plausible explanation for the positive and significant effect of the supply chain network on ESG scores is as follows. A large supply chain network generates greater interconnectedness and communication among network members and consequently promotes information sharing (see Gualandris et al. 2021). In turn, this is expected to improve the distribution of resources, innovation practices and consequently, firms' outcomes in terms of productivity and profits. This provides an incentive for firms to apply policies and initiatives via their operations that place greater emphasis on the environment and society. Such developments may have a significant impact on ESG standards (e.g., carbon emissions and waste, employee diversity and transparency towards stakeholders). Overall, higher ESG standards could be associated with greater valuation by investors who focus on firms

TABLE 4 | The relationship between supply chain network and ESG performance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ESG	E	S	G	ESG	E	S	G
EIGEN	50.360*** (17.028)	124.709*** (23.180)	29.885 (20.106)	16.498 (29.336)				
LN(NODES)					0.262*** (0.083)	0.527*** (0.112)	0.149 (0.098)	0.279** (0.142)
GENDER	4.657*** (0.579)	4.236*** (0.797)	3.821*** (0.693)	5.001*** (1.027)	4.669*** (0.579)	4.249*** (0.797)	3.826*** (0.693)	4.972*** (1.027)
NATION	−0.361 (0.502)	1.368** (0.692)	0.874 (0.600)	−2.522*** (0.889)	−0.339 (0.502)	1.438** (0.692)	0.887 (0.600)	−2.522*** (0.889)
EDUC	2.368*** (0.539)	2.079*** (0.736)	2.473*** (0.638)	1.933** (0.933)	2.395*** (0.539)	2.120*** (0.737)	2.489*** (0.639)	1.965** (0.933)
EXP	0.179*** (0.037)	0.148*** (0.052)	0.234*** (0.045)	0.076 (0.066)	0.178*** (0.037)	0.145*** (0.052)	0.233*** (0.045)	0.076 (0.066)
NETWORK	−0.051 (0.044)	−0.044 (0.060)	−0.023 (0.052)	−0.093 (0.075)	−0.053 (0.044)	−0.050 (0.060)	−0.025 (0.052)	−0.093 (0.075)
BSIZE	0.014 (0.021)	−0.017 (0.029)	0.056** (0.025)	0.043 (0.037)	0.014 (0.021)	−0.016 (0.029)	0.056** (0.025)	0.044 (0.037)
TOBINQ	0.003 (0.131)	0.019 (0.177)	0.155 (0.154)	−0.216 (0.223)	−0.003 (0.131)	0.005 (0.177)	0.152 (0.154)	−0.224 (0.223)
IOWNER	0.028*** (0.008)	−0.003 (0.010)	0.030*** (0.009)	0.051*** (0.013)	0.028*** (0.008)	−0.003 (0.010)	0.030*** (0.009)	0.052*** (0.013)
LN(TA)	1.852*** (0.240)	3.015*** (0.326)	1.797*** (0.281)	1.107*** (0.408)	1.872*** (0.240)	3.079*** (0.325)	1.810*** (0.280)	1.083*** (0.407)
INEF	−0.057 (0.055)	−0.008 (0.073)	−0.095 (0.068)	−0.018 (0.093)	−0.052 (0.055)	0.003 (0.073)	−0.093 (0.068)	−0.012 (0.093)
LIQUID	0.246 (0.280)	0.026 (0.387)	0.499 (0.333)	−0.303 (0.477)	0.246 (0.280)	0.029 (0.387)	0.499 (0.333)	−0.314 (0.477)
LEV	−0.304*** (0.073)	−0.262*** (0.101)	−0.327*** (0.087)	−0.256** (0.126)	−0.304*** (0.073)	−0.261*** (0.101)	−0.328*** (0.087)	−0.257** (0.126)
CONS	0.085 (3.268)	−29.455*** (4.475)	3.554 (3.829)	22.680*** (5.552)	−0.733 (3.288)	−30.923*** (4.504)	3.094 (3.852)	21.557*** (5.583)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Year×Sector FE	Y	Y	Y	Y	Y	Y	Y	Y
N	12,934	13,427	12,520	12,168	12,934	13,427	12,520	12,168
R ²	0.092	0.109	0.093	0.047	0.093	0.108	0.094	0.049

Note: This table summarises the coefficient estimates of the linear panel data model, outlined in Equation (3). All variables are described in Table 2. The sample period runs from 2005 to 2021. The cross-section comprises a total of 3028 companies that have available ESG scores from LSEG, with a varying number of companies in each year. The model is estimated by means of fixed effects estimation methods. Robust standard errors are indicated in round parentheses. Asterisks ***, ** and * denote the 1%, 5% and 10% levels of significance, respectively.

that demonstrate long-term sustainability. In this regard, our results are in accordance with those reported by Koberg and Longoni (2019), Tamayo-Torres et al. (2019), Truant et al. (2024) and Das (2024), who highlight the important role of the supply chain network in influencing ESG scores.

It is instructive at this point to mention that the environmental component of ESG scores is the main component that responds significantly to the impact of a large supply chain network. It appears that a large supply chain network mainly affects the environmental pillar and thus firms' environmental responsibility. This may be explained by the fact that reduced waste production, the minimisation of carbon emissions and lower greenhouse gas (GHG) emissions, among other environmental factors, have a positive impact on the wider community, as these represent global issues. More specifically, more (less) environmentally sustainable suppliers may enhance (damage) the credibility of firms. In addition, when cost-saving practices are adopted by suppliers (e.g., reductions in emissions), firms may also benefit through lower costs. In turn, this generates a competitive advantage and hence improvements in sustainability performance.⁶ In this regard, Dahlmann and Roehrich (2019) argue that the engagement of supply chain partners helps to address climate change. Moreover, our findings are consistent with those of Qiao et al. (2025), who show that smart supply chain management—through practices such as reverse logistics, energy optimisation and predictive analytics—significantly improves firms' environmental performance. Their results suggest that digital integration within supply chains facilitates resource efficiency and emission reductions.⁷

4.2 | The Direct Relationship Between Supply Chain Network and Financial Performance

Table 5 documents how supply chain network size and centrality relate to firms' financial performance, measured by ROA, ROE, ROS, Tobin's Q and stock returns. Supply chain network measures, both eigenvector centrality and the number of supply chain connections (degree centrality), are positively and significantly associated with ROS in Columns 5 and 10. For the remaining financial indicators, the estimated coefficients are positive but not statistically significant. These findings indicate that the financial performance effects of supply chain networks primarily materialise through operating efficiency. The strong and consistent relationship with ROS highlights the primary channel through which supply chain networks generate financial benefits. ROS captures operating margins and reflects firms' ability to translate sales revenues into operating profits. Firms with larger or more central supply chain networks can benefit from improved coordination, better input sourcing, enhanced logistics efficiency and greater reliability in production and delivery. These advantages translate directly into higher operating margins, as measured by ROS. However, effects on asset-based or market-based performance measures may depend on additional organisational and market-level factors. Similar findings are reported by Dehning et al. (2007) and Kim and Henderson (2015), who also link effective supply chain management with higher operating efficiency. Our results are also in line with other related studies, such as Z. Wang and

Sarkis (2013), Basole et al. (2017) and Luo et al. (2023), in which different financial metrics are employed.

In a more detailed analysis of the impact of eigenvector centrality on ROS, the estimated coefficient equals 0.109, which implies that a one-standard-deviation increase in eigenvector centrality (0.012) increases ROS by approximately 0.0013 percentage points (0.012×0.109). Given a mean ROS of 0.748%, this corresponds to an increase of approximately 0.17% ($[(0.0013/0.748) \times 100\%]$) relative to the sample mean. Overall, relative to the mean ROS (0.748%), the effect is economically moderate but statistically significant. Eigenvector centrality reflects a firm's structural influence within the network, including connections to highly connected partners (Gulati 1998) and enhanced exposure to information and best practice spillovers (Frohlich and Westbrook 2001). Consistent with this mechanism, increases in supply chain centrality are associated with higher operating margins.

For network size, the coefficient on LN(NODES) in the ROS regression is 0.003. With a standard deviation of 2.106, a one-standard-deviation increase in network size is associated with an increase in ROS of approximately 0.0063 percentage points (2.106×0.003), as reported in Table A1. Relative to the mean ROS of 0.748%, this corresponds to an increase of about 0.84% of the sample mean. Although network size exhibits a larger one-standard-deviation effect, it is estimated with weaker statistical precision (10% level), whereas the eigenvector centrality effect is statistically stronger (1% level). Taken together, these results suggest that both network size and structural influence (eigenvector centrality) are directly associated with operating performance. However, eigenvector centrality provides a more precisely estimated relationship.

At the same time, the lack of significant effects for ROA, ROE, Tobin's Q and stock returns suggests that these operational benefits do not translate into broader financial or market gains. ROA and ROE incorporate total assets and equity, so they reflect not only operational performance but also the cost of maintaining and coordinating a large supply chain. Firms with extensive networks must invest heavily in IT systems, logistics and management capacity. These investments increase costs, while coordination challenges and the potential for disruptions reduce net profits (H. L. Chen 2018). From this perspective, transaction cost economics (TCE) provides a complementary interpretive framework for understanding the heterogeneous financial performance effects observed in Table 5 (Williamson 1985). While RDT predicts performance gains from expanded networks due to improved resource access and bargaining power (Pfeffer and Salancik 1978), TCE emphasises that increasing network size and complexity also raise coordination, monitoring and governance costs. Managing multiple suppliers and customers requires investments in information systems, contractual oversight and organisational capacity. These additional costs may partially offset the efficiency gains captured by ROS, particularly when broader performance measures such as ROA, ROE and Tobin's Q incorporate capital intensity and risk exposure.

The insignificant results for Tobin's Q and stock returns suggest that investors also see this trade-off. The market may recognise the efficiency benefits of large networks but also factors in

TABLE 5 | The direct relationship between supply chain network and financial performance.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	TOBINQ	RETURN	ROA	ROE	ROS	TOBINQ	RETURN	ROA	ROE	ROS
EIGEN	-2.035 (1.252)	0.489 (0.814)	0.119 (0.194)	0.355 (0.462)	0.109*** (0.401)					
LN(NODES)						-0.001 (0.006)	0.004 (0.004)	0.001 (0.001)	-0.001 (0.002)	0.003* (0.002)
GENDER	0.016 (0.043)	-0.010 (0.028)	0.012* (0.007)	0.001 (0.016)	1.093 (1.369)	0.015 (0.043)	-0.010 (0.028)	0.012* (0.007)	0.001 (0.016)	1.135 (1.369)
NATION	0.063* (0.037)	0.043* (0.024)	-0.003 (0.006)	-0.024* (0.014)	-0.421 (1.187)	0.062* (0.037)	0.043* (0.024)	-0.003 (0.006)	-0.024* (0.014)	-0.356 (1.187)
EDUC	0.006 (0.040)	0.022 (0.026)	-0.005 (0.006)	-0.017 (0.015)	-1.576 (1.275)	0.006 (0.040)	0.022 (0.026)	-0.004 (0.006)	-0.017 (0.015)	-1.553 (1.275)
EXP	-0.010*** (0.003)	-0.004** (0.002)	0.000 (0.000)	0.003*** (0.001)	0.060 (0.089)	-0.010*** (0.003)	-0.004** (0.002)	0.000 (0.000)	0.003*** (0.001)	0.056 (0.089)
NETWORK	0.000 (0.003)	0.003 (0.002)	-0.000 (0.001)	-0.002** (0.001)	0.114 (0.104)	0.000 (0.003)	0.003 (0.002)	-0.000 (0.001)	-0.002** (0.001)	0.109 (0.104)
BSIZE	-0.007*** (0.002)	-0.000 (0.001)	-0.000 (0.000)	0.002*** (0.001)	-0.021 (0.050)	-0.007*** (0.002)	-0.000 (0.001)	-0.000 (0.000)	0.002*** (0.001)	-0.021 (0.050)
IOWNER	-0.001** (0.001)	-0.001*** (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.008 (0.018)	-0.001** (0.001)	-0.001*** (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.009 (0.018)
LN(TA)	-0.318*** (0.018)	-0.258*** (0.011)	-0.048*** (0.003)	0.021*** (0.006)	-12.388*** (0.562)	-0.320*** (0.018)	-0.258*** (0.011)	-0.048*** (0.003)	0.021*** (0.006)	-12.308*** (0.561)
INEF	-0.001 (0.004)	0.000 (0.003)	-0.006*** (0.001)	-0.001 (0.001)	-0.473*** (0.129)	-0.001 (0.004)	0.001 (0.003)	-0.006*** (0.001)	-0.001 (0.001)	-0.466*** (0.129)
LIQUID	-0.056*** (0.021)	0.036*** (0.014)	-0.009*** (0.003)	-0.012 (0.008)	-2.069*** (0.665)	-0.056*** (0.021)	0.035*** (0.013)	-0.009*** (0.003)	-0.012 (0.008)	-2.062*** (0.665)

(Continues)

TABLE 5 | (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	TOBINQ	RETURN	ROA	ROE	ROS	TOBINQ	RETURN	ROA	ROE	ROS
LEV	-0.028*** (0.005)	0.091*** (0.004)	-0.001 (0.001)	0.043*** (0.002)	0.364** (0.173)	-0.028*** (0.005)	0.091*** (0.004)	-0.001 (0.001)	0.043*** (0.002)	0.369** (0.173)
CONS	4.112*** (0.237)	1.169*** (0.154)	0.708*** (0.037)	0.226*** (0.088)	214.619*** (7.598)	4.102*** (0.239)	1.155*** (0.155)	0.702*** (0.037)	0.232*** (0.088)	213.973*** (7.650)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year×Sector FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
N	12,725	12,769	12,695	12,689	12,769	12,725	12,769	12,695	12,689	12,769
R ²	0.159	0.045	0.072	0.039	0.034	0.156	0.045	0.072	0.038	0.032

Note: This table summarises the coefficient estimates of the linear panel data model, outlined in Equation (3). All variables are described in Table 2. The sample period runs from 2005 to 2021. The cross-section comprises a total of 3028 companies that have available ESG scores from LSEG, with a varying number of companies in each year. The model is estimated by means of fixed effects estimation methods. Robust standard errors are indicated in round parentheses. Asterisks ***, ** and * denote the 1%, 5% and 10% levels of significance, respectively.

the greater exposure to systemic supply chain risks (Carvalho et al. 2020; Gao 2020). As a result, the net market valuation effect is neutral, which is consistent with our finding that stock performance is unaffected, unlike in Luo et al. (2023), where network effects may have operated in a different market context.

Overall, these results show that the main benefit of an extensive supply chain network lies in operational efficiency, reflected in higher ROS. Once capital costs, coordination frictions and risk exposures are taken into account, the broader financial and market outcomes balance out. In short, firms gain efficiency from being well connected, but the complexity of managing large networks limits how much of that efficiency translates into higher firm value.⁸

4.3 | The Indirect Relationship Between Supply Chain Network and Financial Performance—Simultaneous Equations

Our findings in Sections 4.1 and 4.2 suggest that firms operating within extensive supply chain networks exhibit significantly higher ESG performance, while financial performance improvements are more modest and mainly captured by the ROS metric. The absence of strong effects on other financial indicators such as ROA, ROE, Tobin's *Q* and stock returns implies that the mechanism through which supply chain networks affect firm value is likely to be *indirect*, operating through ESG performance. This interpretation is consistent with the Pfeffer and Salancik (1978) application of RDT, which, as demonstrated earlier, explains the *direct* benefits of network centrality for resource access and operational performance. However, when firms' value enhancement depends on sustainability factors, the mechanism appears mediated by ESG dynamics rather than purely direct effects.

Supporting evidence from recent studies strengthens this interpretation. For instance, Le Tran and Coqueret (2023) document that ESG-related news from firms' supply chains represents a strong trading signal for investors, which significantly influences both firm and partner (i.e., customer and supplier) returns. The authors show that stock returns react instantaneously to ESG shocks and that these effects propagate through the supply chain with short lags, indicating a spillover mechanism. Positive ESG news attracts sustainable investors, while negative news deters them. Consequently, changes in ESG performance generate rapid yet transient adjustments in market valuations, which implies that financial performance may not respond immediately to changes in network structure but rather through ESG channels.

Our indirect effect framework consists of three steps. The first two steps have already been discussed in Sections 4.1 and 4.2. Specifically, we first examine the direct impact of the supply chain network on ESG scores using baseline panel regressions. Second, we analyse the direct association between supply chain network measures and financial performance, again relying on baseline panel regressions. In the third step, we formally test the indirect role of ESG performance in the relationship between network centrality and firm valuation. To do so, we implement a simultaneous equations framework estimated via three-stage least squares (3SLS), which allows us to account for the joint

determination of ESG performance and firm value and to address potential endogeneity concerns. This framework captures the reciprocal feedback between ESG and Tobin's Q , while explicitly incorporating firms' network position (measured by eigenvector centrality). Overall, the indirect effect analysis helps to clarify that the impact of network centrality on firm valuation does not primarily operate directly. Instead, it works indirectly: centrality strengthens ESG performance and stronger ESG performance enhances firm value. ESG therefore functions as the transmission mechanism linking supply chain network position to market valuation.

The selection of Tobin's Q is primarily motivated by the existing literature. Unlike accounting-based measures such as ROA or ROE, which reflect historical performance and are sensitive to accounting conventions, Tobin's Q incorporates investors' expectations about future profitability and growth opportunities through market valuation (see, e.g., Anderson et al. 2004; Peloza 2009). Moreover, Tobin's Q is comparable across firms and industries and is less distorted by differences in accounting practices, while also capturing the value of intangible assets such as innovation, governance quality and strategic capabilities (see, e.g., Ravichandran et al. 2009; Bebhuk and Weisbach 2010; Aggarwal and Dow 2012). Consequently, it has become the preferred metric in marketing, management, sustainability and ESG research for evaluating long-term firm value and market confidence (see, for example, Gallego-Álvarez et al. 2014; Yu et al. 2018; Rahat and Nguyen 2024).

Higher ESG performance may enhance valuation through signalling effects, as discussed earlier, whereas more valuable firms may also invest more in sustainability initiatives, thus creating simultaneity bias if ignored. At the same time, our previous panel estimations show that supply chain networks do not significantly affect all financial performance measures. However, because firms' network positions (proxied by eigenvector centrality) are relatively stable and determined by long-term inter-firm relationships, we treat the supply chain network as an exogenous variable in the system. The 3SLS specification therefore enables us to disentangle these intertwined relationships and identify whether the influence of network centrality operates primarily through ESG performance. The model is outlined below:

$$\begin{aligned} \text{TOBINQ} = & \alpha_0 + \alpha_1 \text{ESG}_{i,t-1} + \alpha_2 \text{EIGEN}_{i,t-1} + \alpha'_3 \text{Board}_{i,t-1} \\ & + \alpha'_4 \text{Financial}_{i,t-1} + \alpha'_5 \text{Year}_t + \alpha'_6 \text{Sector}_j + u_{i,t}, \end{aligned} \quad (4)$$

$$\begin{aligned} \text{ESG} = & \beta_0 + \beta_1 \text{EIGEN}_{i,t-1} + \beta_2 \text{TOBINQ}_{i,t-1} + \beta'_3 \text{Board}_{i,t-1} \\ & + \beta'_4 \text{Financial}_{i,t-1} + \beta'_5 \text{Year}_t + \beta'_6 \text{Sector}_j + u_{i,t}. \end{aligned} \quad (5)$$

These equations assume that Tobin's Q and ESG are endogenously related: Tobin's Q is influenced by both ESG and EIGEN (we employ eigenvector centrality as a proxy for the supply chain network), whereas ESG is shaped by EIGEN and Tobin's Q . Following Jo et al. (2007) and Hahn and Hausman (2003), we include only statistically significant variables to ensure robust identification and avoid weak instruments.⁹ For brevity, we report results for Tobin's Q and EIGEN in Table 6, and we note that

TABLE 6 | The indirect relationship between supply chain network and financial performance—simultaneous equations.

	(1) TOBINQ	(2) ESG
TOBINQ		2.222*** (0.148)
ESG	0.011*** (0.001)	
EIGEN	−0.697 (0.978)	29.146** (13.356)
GENDER		8.702*** (0.587)
NATION	0.011 (0.031)	
EDUC		3.398*** (0.535)
EXP	−0.005 (0.003)	0.233*** (0.047)
BSIZE	−0.003*** (0.001)	
IOWNER	−0.002*** (0.001)	0.022*** (0.008)
LN(TA)	−0.267*** (0.008)	6.830*** (0.106)
LIQUID	−0.142*** (0.026)	
LEV	−0.168*** (0.006)	−0.656*** (0.100)
CONS	3.424*** (0.066)	−20.714*** (1.122)
Year FE	Y	Y
Sector FE	Y	Y
N	10,488	10,488
R^2	0.261	0.438

Note: This table summarises the coefficient estimates of the 3SLS model, outlined in Equations (4) and (5). All variables are described in Table 2. The sample period runs from 2005 to 2021. The cross-section comprises a total of 3028 companies that have available ESG score from LSEG, with a varying number of companies in each year. The model is estimated by means of fixed effects estimation methods. Robust standard errors are indicated in round parentheses. Asterisks ***, ** and * denote the 1%, 5% and 10% levels of significance, respectively.

results for other financial variables are qualitatively similar and available upon request. The 3SLS estimates confirm a mutually reinforcing relationship: Tobin's Q and EIGEN both exert positive effects on ESG, while higher ESG scores, in turn, improve

firm valuation. Importantly, the effect of EIGEN on Tobin's Q is indirect, as it operates exclusively through ESG. This lends empirical support to our third hypothesis and confirms that supply chain networks directly influence ESG outcomes but enhance financial performance mainly indirectly, through sustainability channels.

This indirect mechanism highlights how inter-firm linkages transmit sustainability practices and how managing external relationships contributes to long-term value creation in a sustainability-focused environment. While Sections 4.1 and 4.2 demonstrated that RDT explains the direct effects of supply chain centrality on resource access and operational performance, the present evidence suggests that the indirect effects are better understood through the lens of signalling theory (Spence 1973). Firms use ESG engagement to signal long-term orientation and responsible management, which enhances credibility, reduces perceived uncertainty and improves market valuation. Within extensive supply chain networks, this signalling effect is amplified by visibility, information diffusion and stakeholder interdependence.

Recent empirical studies further reinforce these findings by demonstrating the broader implications of ESG performance for firms' financial and operational dimensions. For instance, Ariefianto et al. (2025) show that ESG scores significantly reduce firms' cost of debt—through reputation development and by providing complementary information beyond traditional risk metrics. Asteriou et al. (2025) report that, at the aggregate country-group level, low-ESG countries deliver higher average returns for investors than high-ESG countries, while high-ESG countries outperform medium-ESG countries. However, within each country group, higher ESG scores are positively associated with returns. Bagh et al. (2025) find that firms with stronger ESG performance benefit from lower financing costs, as they are perceived as less risky by investors. Similarly, Beloskar and Nageswara Rao (2024) show that ESG scores can be used by investors in order to construct and benefit from equally weighted best-in-class portfolios. Piserá et al. (2025) find that ESG scores are associated with higher firm total factor productivity. Finally, J. Chen et al. (2025) imply that ESG score uncertainty increases firms' cost of debt financing and creditors' fears about firms' risks and disclosure quality.

4.4 | The Effects of the California Transparency in Supply Chains Act on ESG and Financial Performance

To evaluate whether our results are influenced by regulatory pressures as an exogenous shock, we employ a difference-in-differences (DiD) approach that seeks to scrutinise the financial and nonfinancial effects of the California Transparency in Supply Chains Act (CTSCA). Enacted in January 2012, the CTSCA requires large retailers and manufacturers doing business in California (with annual worldwide revenues exceeding \$100 million) to publicly disclose their efforts to eradicate slavery and human trafficking from their direct supply chains. This law linked corporate supply chain operations to legally mandated transparency obligations. Therefore, it is natural to determine

whether this law influenced the ESG performance of firms. Arguably, the Act's introduction can be thought of as a quasi-natural experiment. Indeed, firms with high centrality in supply chains that operate in California were suddenly subject to new ESG-related compliance and disclosure requirements, while similar firms in other US states remained largely unaffected. This regulatory divergence helps us isolate the impact of the CTSCA on ESG outcomes and financial performance by comparing firms in California before and after 2012 against those in less regulated states over the same period. The approach allows us to examine whether increased transparency obligations lead to improved ESG and financial outcomes.

Therefore, we estimate the following DiD model, similar to Lin and Zhu (2025):

$$Y_{i,t} = \alpha_0 + \alpha_1 \text{Treated}_{i,t} \times \text{Post}_{CA,i,t} + \alpha_2 \text{Treated}_{i,t} + \alpha_3 \text{Post}_{CA,i,t} + \alpha'_4 \text{Board}_{i,t-1} + \alpha'_5 \text{Financial}_{i,t-1} + \alpha'_6 \text{Year}_t + \alpha'_7 \text{Year}_t \times \text{Sector}_j + u_{i,t}, \quad (6)$$

where $Y_{i,t}$ denotes either ESG scores or financial performance as the dependent variable. $\text{Treated}_{i,t}$ is a dummy variable that equals 1 if a firm is highly central within its supply chain network (i.e., its eigenvector centrality score is above the annual median) and 0 otherwise. $\text{Post}_{CA,i,t}$ is a dummy variable that equals 1 for the years 2012 and beyond, but only for firms operating in California and 0 otherwise.

The results presented in Table 7 show that ESG scores increase significantly for treated firms in California after 2012, suggesting an exogenous regulatory effect. This implies that firms at the core of supply chain networks respond positively to state-level transparency legislation. We argue that the Act mandates that such firms strengthen their ESG practices through more thorough audits and disclosures to meet the law's requirements. Conversely, firms in less regulated states do not face the same level of pressure (for example, firms in Texas), and thus the incentive to improve ESG scores is weaker.

This finding can also be interpreted through the lens of institutional theory (DiMaggio and Powell 1983) that highlights the normative and mimetic pressures within an industry or network (also see Wiredu et al. 2024). In this regard, the CTSCA appeared to trigger normative and mimetic responses across interconnected firms, prompting them to conform to new sustainability and transparency norms. Hence, the observed ESG improvements among treated firms are consistent with external institutional pressures (legislation) that promote the diffusion of responsible business practices throughout supply chain networks.

Finally, we observe no statistically significant change in financial performance. One potential explanation is that compliance with the Act increases operational costs, particularly for firms that manage and monitor extensive supply chain networks. These additional expenses may offset any potential financial benefits in the short run, even if longer-term benefits eventually emerge.

TABLE 7 | The effects of California Transparency in Supply Chains Act on ESG and financial performance—difference-in-differences approach.

	(1) ESG	(2) ESG	(3) ESG	(4) TOBINQ	(5) TOBINQ	(6) TOBINQ
TREATED×POST	1.802** (0.746)	1.351* (0.770)	1.192* (0.650)	0.027 (0.039)	0.042 (0.040)	−0.084 (0.085)
TREATED		0.714** (0.306)	0.730* (0.381)		−0.030* (0.017)	−0.018 (0.021)
POST			0.355 (1.693)			0.211** (0.096)
CONS	0.189 (3.095)	0.099 (3.095)	0.072 (4.957)	3.661*** (0.127)	3.668*** (0.127)	3.648*** (0.168)
All controls	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Year×Sector FE	Y	Y	Y	Y	Y	Y
N	12,132	12,132	12,132	12,391	12,391	12,391
R ²	0.115	0.114	0.114	0.070	0.072	0.072

Note: This table summarises the coefficient estimates of the difference-in-differences model, outlined in Equation (6). All variables are described in Table 2. The sample period runs from 2005 to 2021. The cross-section comprises a total of 3028 companies that have available ESG score from LSEG, with a varying number of companies in each year. The model is estimated by means of fixed effects estimation methods. Robust standard errors are indicated in round parentheses. Asterisks ***, ** and * denote the 1%, 5% and 10% levels of significance, respectively.

5 | Robustness Checks

5.1 | The Effects of Supply Chain Network on ESG and Financial Performance—Controlling for Firm's Emissions and Age

In this section, we analyse the robustness of our results. We examine whether our results alter when we split our sample between low- and high-polluting firms, as well as between old and new firms (by firm age). To this end, we use the median GHG emissions scaled by total assets. Similarly, we consider the median firm age of our sample, that is, 21 years since establishment.

With reference to low- and high-polluting firms, the rationale behind our decision is that high GHG firms are mainly associated with the materials, industrials and utilities sectors and therefore, are more dependent on a large supply chain network. Indeed, such sectors are closely dependent on the physical movement of their products to customers. In contrast, for low-emission firms such as financials and health care sectors, a large supply chain network might not be so important for these firms' operations. We argue that such sectors are mainly providers of intangible services, such as money transfers and users of online platforms. Thus, we expect that such sectors do not rely on a physical distribution of products. Turning to firm age, older firms might have a more established supply chain network in terms of reputation, collaboration, management and resources than younger firms. This implies that it is easier for older firms to shift among suppliers and establish new practices.

Tables 8 and 9 report the results for ESG and financial performance, respectively. Moreover, Panels A and B distinguish between low- and high-emission firms, while Panels C and D distinguish between new and old firms. Both tables show that our results remain qualitatively similar. Particularly, H1 is confirmed, in that a large supply chain network increases firms' ESG scores, while H2 is not fully confirmed, as a large supply chain network does not affect financial performance with the exception of ROS. The importance of ROS accords with our empirical findings described in the previous section.

In a more detailed analysis, Table 8 shows a positive and significant impact of a large supply chain network that is generally confirmed in all panels, for both low- and high-polluting firms as well as old and new firms. More importantly, we notice that this impact is more prevalent among high-polluting firms and old firms. This is in line with our expectation, which indicates that high-polluting firms are more dependent on their supply chain networks, given their significant environmental impact and the need to generate sustainability practices. We also observe that a large supply chain network consistently exerts a highly significant impact on the environmental pillar in all panels in comparison with the other pillars. Finally, old firms appear to take advantage of having long-term relationships with suppliers. As we previously mentioned, such a relationship involves trust, reliability and better collaboration between these firms and their suppliers.

Similarly, with reference to low- and high-emission firms, Table 9 shows that ROS is the metric that is positively and

TABLE 8 | The relationship between supply chain network and ESG performance—robustness checks.

	(1) ESG	(2) E	(3) S	(4) G	(5) ESG	(6) E	(7) S	(8) G
Panel A: Low GHG emission firms								
EIGEN	48.407*	149.643***	72.396**	−36.368				
	(27.858)	(40.514)	(33.143)	(48.203)				
LN(NODES)					0.213*	0.602***	0.255*	0.013
					(0.119)	(0.172)	(0.141)	(0.206)
All controls	Y	Y	Y	Y	Y	Y	Y	Y
<i>N</i>	4821	5056	4664	4531	4821	5056	4664	4531
<i>R</i> ²	0.096	0.123	0.069	0.080	0.096	0.120	0.069	0.082
Panel B: High GHG emission firms								
EIGEN	103.221***	126.983***	83.198**	61.544				
	(29.965)	(40.371)	(36.062)	(50.627)				
LN(NODES)					0.656***	0.741***	0.680***	0.260
					(0.199)	(0.268)	(0.238)	(0.333)
All controls	Y	Y	Y	Y	Y	Y	Y	Y
<i>N</i>	4725	4852	4583	4416	4725	4852	4583	4416
<i>R</i> ²	0.025	0.163	0.015	0.018	0.027	0.166	0.014	0.020
Panel C: Newly established firms								
EIGEN	37.562	147.560***	30.636	−23.354				
	(25.098)	(33.559)	(29.275)	(43.426)				
LN(NODES)					0.234**	0.469***	0.079	0.216
					(0.117)	(0.155)	(0.135)	(0.200)
All controls	Y	Y	Y	Y	Y	Y	Y	Y
<i>N</i>	6072	6433	5901	5977	6072	6433	5901	5977
<i>R</i> ²	0.072	0.023	0.069	0.065	0.072	0.019	0.069	0.071
Panel D: Mature firms								
EIGEN	67.855***	98.764***	45.894	23.754				
	(24.047)	(33.099)	(28.958)	(42.320)				
LN(NODES)					0.458***	0.540***	0.395***	0.426**
					(0.124)	(0.171)	(0.150)	(0.217)
All controls	Y	Y	Y	Y	Y	Y	Y	Y
<i>N</i>	6571	6691	6331	5921	6571	6691	6331	5921
<i>R</i> ²	0.046	0.178	0.058	0.006	0.049	0.182	0.058	0.006

Note: This table summarises the coefficient estimates of the linear panel data model, outlined in Equation (3). All variables are described in Table 2. The sample period runs from 2005 to 2021. The cross-section comprises a total of 3028 companies that have available ESG score from LSEG, with a varying number of companies in each year. The model is estimated by means of fixed effects estimation methods. Robust standard errors are indicated in round parentheses. Asterisks ***, ** and * denote the 1%, 5% and 10% levels of significance, respectively.

significantly affected by a large supply chain network. As regards low-emission firms, a plausible interpretation for the positive impact on ROS can be attributed to the fact that they collaborate with green suppliers, while a reasonable explanation for the positive impact on ROS among high-emissions

firms is that they may have access to an extensive number of suppliers who are devoted to sustainability. In both cases, low- and high-emission firms could gain benefits from a large supply network in terms of higher environmental standards, cost savings and higher efficiency, thereby increasing ROS.

TABLE 9 | The direct relationship between supply chain network and financial performance—robustness checks.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	TOBINQ	RETURN	ROA	ROE	ROS	TOBINQ	RETURN	ROA	ROE	ROS
Panel A: Low GHG emission firms										
EIGEN	−0.256	0.592	0.522	0.188	0.142***					
	(2.637)	(1.452)	(0.350)	(0.611)	(0.544)					
LN(NODES)						0.008	0.006	0.002	−0.002	0.004*
						(0.011)	(0.006)	(0.001)	(0.003)	(0.002)
All controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
<i>N</i>	4797	4821	4775	4772	4821	4797	4821	4775	4772	4821
<i>R</i> ²	0.082	0.034	0.006	0.022	0.002	0.080	0.034	0.006	0.021	0.002
Panel B: High GHG emission firms										
EIGEN	−3.382**	0.624	0.152	0.362	0.252***					
	(1.468)	(1.197)	(0.259)	(0.775)	(0.687)					
LN(NODES)						−0.027***	0.002	−0.001	0.006	0.009**
						(0.010)	(0.008)	(0.002)	(0.005)	(0.004)
All controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
<i>N</i>	4717	4725	4721	4720	4725	4717	4725	4721	4720	4725
<i>R</i> ²	0.043	0.079	0.238	0.021	0.132	0.045	0.080	0.243	0.019	0.131
Panel C: Newly established firms										
EIGEN	−3.533*	1.891	0.288	1.007	0.186***					
	(2.118)	(1.426)	(0.343)	(0.779)	(0.653)					
LN(NODES)						−0.009	0.010	0.003**	0.000	0.006**
						(0.010)	(0.007)	(0.002)	(0.004)	(0.003)
All controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
<i>N</i>	5990	6015	5978	5976	6014	5990	6015	5978	5976	6014
<i>R</i> ²	0.239	0.043	0.082	0.021	0.030	0.236	0.043	0.084	0.018	0.026
Panel D: Mature firms										
EIGEN	0.112	−0.176	−0.035	−0.455	0.756					
	(1.551)	(1.024)	(0.238)	(0.604)	(0.534)					
LN(NODES)						0.011	0.003	−0.001	−0.006**	0.001
						(0.008)	(0.005)	(0.001)	(0.003)	(0.001)
All controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
<i>N</i>	6446	6465	6431	6427	6466	6446	6465	6431	6427	6466
<i>R</i> ²	0.099	0.046	0.067	0.028	0.050	0.096	0.047	0.068	0.029	0.049

Note: This table summarises the coefficient estimates of the linear panel data model, outlined in Equation (3). All variables are described in Table 2. The sample period runs from 2005 to 2021. The cross-section comprises a total of 3028 companies that have available ESG score from LSEG, with a varying number of companies in each year. The model is estimated by means of fixed effects estimation methods. Robust standard errors are indicated in round parentheses. Asterisks ***, ** and * denote the 1%, 5% and 10% levels of significance, respectively.

Finally, regarding old and new firms, ROS is significantly affected by a large supply chain network in the case of new firms only. Although a large supply chain network may add complexity to new firms due to their lack of relevant experience

to operate within a complex environment, we could argue that new firms may potentially benefit in terms of access to resources, brand reputation and higher product demand. In turn, such advantages may contribute to improvements in

ROS and consequently to firms' operational efficiency and profitability.

5.2 | The Relationship Between Supply Chain Network and Supply Chain ESG

In order to gain a clearer understanding of the aforementioned relations, we perform two additional tasks. First, we seek to determine whether a firm with extensive supply chain connections can influence its network to improve its members' ESG scores. In other words, we measure the average ESG scores of a firm's supply chain network to test if these scores increase when a firm has a high eigenvector centrality or a large number of supply chain connections (degree centrality). Second, we test whether a firm with extensive supply chain connections can induce firms within its supply chain network to reduce differences in their ESG scores (ESG score spread). The results confirming that a firm with a large supply chain network plays a key role in determining and influencing developments related to ESG scores within its network are presented in Table 10.

Our results provide evidence that within a large supply chain network, an influential firm improves the performance of other firms in terms of their ESG scores. In fact, both measures of supply chain network show that a dominant firm exerts a positive and significant impact on other firms in the network by putting pressure on them in order to meet ESG expectations. Similarly, our findings confirm the key role of a dominant firm within a large supply chain network in reducing the ESG score spread among firms in its supply network. Put differently, it helps to reduce the gap between the highest and lowest ESG scores. This is evident from the negative coefficient; however, it is statistically

significant only for the measure of supply chain connections (degree centrality). Overall, we argue that a dominant central firm could drive positive developments via practices such as the minimisation of waste, the adoption of new technologies and the promotion of diversity, which all contribute to the improvement of ESG standards within the dominant firm's extensive supply chain network.

6 | Conclusion

In this study, we investigate the relationship between a large supply chain network, approximated by either eigenvector centrality or the number of supply chain connections (degree centrality) and firms' ESG scores and financial performance. The ESG scores refer to the three ESG pillars. The financial performance includes ROA, ROE, ROS, Tobin's *Q* and firms' stock returns. We employ a panel data model in which we include a set of control variables in order to mitigate omitted-variable bias. Our dataset covers the period from January 2005 to December 2021. This study expands the existing literature by examining the impact of a large supply chain network on both financial and non-financial metrics and provides a comprehensive analysis of the relationships under examination.

Our findings are briefly summarised as follows. First, a large supply chain network has a positive and significant effect on ESG scores. This impact is more prevalent for the environmental pillar, highlighting the importance of more environmentally sustainable suppliers. Second, a large supply chain network appears to exert an insignificant effect on financial performance, with the exception of ROS. This implies that supply chain network density mainly affects financial performance through operational efficiency. Third, our main analysis confirms that

TABLE 10 | The relationship between supply chain network and supply chain ESG—robustness checks.

	NETWORK ESG		ESG SPREAD	
	(1)	(2)	(3)	(4)
EIGEN	25.371*** (5.611)		−7.305 (16.963)	
LN(NODES)		0.271*** (0.029)		−0.349*** (0.088)
CONS	37.180*** (0.743)	36.127*** (0.753)	21.562*** (3.012)	23.114*** (3.034)
All controls	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Year×Sector FE	Y	Y	Y	Y
<i>N</i>	22,175	22,175	11,942	11,942
<i>R</i> ²	0.411	0.404	0.010	0.010

Note: This table summarises the coefficient estimates of the linear panel data model, outlined in Equation (3). All variables are described in Table 2. The sample period runs from 2005 to 2021. The cross-section comprises a total of 3028 companies that have available ESG score from LSEG, with a varying number of companies in each year. The model is estimated by means of fixed effects estimation methods. Robust standard errors are indicated in round parentheses. Asterisks ***, ** and * denote the 1%, 5% and 10% levels of significance, respectively.

a large supply chain network directly affects ESG scores and indirectly influences financial performance. Finally, we provide evidence in favour of RDT and signalling theory.

Our findings raise important policy implications, in particular for governments, industry and investors. By focusing on the relationship between supply chain networks and ESG scores, an important industry implication is that focal firms should pay attention to the critical role of their supply chain network to achieve environmental benefits in terms of a low carbon footprint, including the use of more environmentally friendly materials. A government implication is the provision of tax incentives or subsidies for those firms that contribute to improvements in ESG scores via the sustainable management of large supply chain networks. Moreover, a large supply chain network that generates high ESG scores provides incentives for investors to invest their funds in firms that achieve such outcomes.

Furthermore, our findings reveal policy implications when we emphasise the relationship between supply chain networks and financial performance. For example, an important industry implication is that focal firms with a large supply chain network could reduce operational costs via improvements in their efficiency. In turn, the adoption of such practices helps focal firms generate value across the supply chain network and thus increase shareholder value, which encourages investors to include such firms in their investment decisions. What is more, governments could provide financial incentives for those firms that improve financial metrics via a large supply chain network, such as tax deductions for investments in their networks aimed at strengthening them. In retrospect, all the aforementioned policy implications that focus on the optimisation of large supply chain networks can decisively contribute to creating more sustainable prospects for overall economic activity.

Future research may examine alternative proxies for financial performance focusing on risk, such as systematic risk, among others. Second, the incorporation of countries other than the United States, such as Japan or the United Kingdom, among others, is another promising area for future work. Third, the examination of the relationship between supply chain networks and GHG emissions is another avenue for future research, given that supply chains are responsible for a significant proportion of GHG emissions. Fourth, it would be interesting to examine the impact of ESG scores on financial performance via the channel of attracting sophisticated investors with a long-term orientation (see Economidou et al. 2023). Fifth, research indicates that, to fully leverage the competitive advantages offered by interorganisational network ties, lead firms need to carefully manage their network structures (Capaldo 2007).¹⁰ Finally, research could examine how ESG-linked executive compensation influences sustainability practices across the supply chain. This line of enquiry is particularly timely in light of the EU Corporate Sustainability Due Diligence Directive (Directive [EU] 2024/1760), which requires companies to identify, prevent, mitigate and remedy adverse environmental and human rights impacts across their operations and value chains (see <https://eur-lex.europa.eu/eli/dir/2024/1760/oj>).

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Conflicts of Interest

The authors declare no conflicts of interest.

Endnotes

¹ <https://www.mckinsey.com/capabilities/operations/our-insights/moving-supply-chain-leaders-to-the-c-suite>.

² <https://corporatefinanceinstitute.com/resources/management/supply-chain/>.

³ The source of the information can be found on the European Parliament: <https://www.europarl.europa.eu/news/en/press-room/20220620IPR33413/new-social-and-environmental-reporting-rules-for-large-companies>.

⁴ Evidence from studies employing context-aware global business networks shows that portfolios formed on the basis of these economic connections generate statistically significant positive abnormal returns, which reach up to 281 basis points per month in global samples, and outperform portfolios constructed using traditional industry classifications (Breitung and Müller 2025).

⁵ We indicate that Tobin's Q (i) is included as a financial control variable when we run the model regarding the ESG scores and (ii) is considered as a dependent variable when we run the model associated with the financial performance. The rest of the control variables either financial or board remain the same in both models.

⁶ For more information, we refer the reader to US Environmental Protection Agency (EPA). The source of the information can be found on: <https://www.epa.gov/climateleadership/supply-chain-guidance>.

⁷ Our results from Table 4 reveal the important role of the control variables under consideration. We refer to Gender and Education from the set of Board variables, as well as the LN(TA) and Leverage, from the set of Financial variables. With reference to the link between a large supply network and ESG scores, a higher proportion of women who occupy board member positions leads to a positive impact on ESG performance as they appear to be more concerned with ESG issues. Arayssi et al. (2016) report that a high participation of women on corporate boards leads to a more reliable firms' sustainability reporting and a positive effect on the ESG-performance sensitivity. In the same line of reasoning, Marie et al. (2025) indicate that there is a positive relationship between ESG scores and corporate cash holdings when the number of women on the board is increasing. Moreover, education contributes positively to ESG scores as higher education of executives raises awareness of ESG risks. According to Wan et al. (2023), the educational backgrounds of the CEO and the chairman of the supervisory board are important factors to exert an impact on ESG practices. Furthermore, leverage as a proxy of firm risk, appears to negatively impact the ESG scores as higher firm risks are more likely to drive firms to focus on the probability of default rather than the improvement of ESG scores. The negative relationship between leverage and

ESG scores has been documented by Asimakopoulos et al. (2024). Finally, the size of the firm—measured as the natural logarithm of firm's total assets—exerts a positive impact ESG performance. This is because large firms have the necessary resources to invest in ESG and improve their ESG outcomes.

⁸ We also scrutinise the effects of the control variables. For instance, Table 5 documents the importance of the firm size, measured as the natural logarithm of firm's total assets, which has a negative effect on corporate financial performance, likely because larger firms experience diseconomies of scale that lead to lower profitability and operational inefficiencies.

⁹ Significant control variables are discussed in Sections 4.1 and 4.2.

¹⁰ Specifically, Capaldo (2007) finds that the ability to integrate a wide range of diverse, weaker connections on the periphery with a core of strong ties is a unique relational capability. This capability allows leading firms in networks to achieve sustainable competitive advantages, primarily driven by dynamic innovative capabilities.

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Appendix A

TABLE A1 | Economic interpretation of significant coefficients.

Explanatory variable	Dependent variable	Economic magnitude	
		1 SD effect	% of mean
Results from Table 4			
EIGEN	ESG (Column 1)	0.60 points	1.48%
EIGEN	E (Column 2)	1.50 points	5.65%
LN(NODES)	ESG (Column 5)	0.55 points	1.35%
LN(NODES)	E (Column 6)	1.11 points	4.18%
Results from Table 5			
EIGEN	ROS (Column 5)	0.0013 pp	0.17%
LN(NODES)	ROS (Column 10)	0.0063 pp	0.84%

Note: This table reports the economic magnitudes associated with the statistically significant coefficients presented in Tables 4 and 5. Economic magnitudes are calculated as the product of the estimated regression coefficient and the sample standard deviation of the respective explanatory variable, thereby capturing the effect of a one-standard-deviation increase in the supply chain network measure. For ESG-related outcomes, effects are reported in ESG score points. For return on sales (ROS), which is expressed in percentage terms, effects are reported in percentage points (pp). The column ‘% of mean’ expresses each one-standard-deviation effect relative to the sample mean of the corresponding dependent variable (see Table 3 for descriptive statistics). This scaling facilitates comparison of economic significance across outcome variables measured on different scales.