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Green supply chain management for carbon accountability

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As disclosure mandates shift their focus towards supply chain carbon accountability, firms are compelled to enhance carbon outcomes throughout their supply chain. The literature suggests that green supply chain management (hereafter, GSCM) plays an essential role in enhancing firms' environmental performance. However, there is a dearth of evidence on the possible informational effects of GSCM on Scope 3 carbon outcomes despite their mutual linkage to supply chains. Using two novel measures of GSCM quality, defined as the extent to which environmental objectives are integrated into supply chain management processes, we find that higher GSCM quality increases the likelihood of a focal customer's Scope 3 carbon disclosures and reduces its Scope 3 carbon footprint. These effects of GSCM quality are realized through improvements in relational trust among customer-supplier relationships and in suppliers' environmental innovation capabilities. Further analysis reveals that the effects of GSCM quality are realized among durable customer-supplier relationships. We identify GSCM quality as an essential and distinct component of corporate environmental governance. These findings highlight the importance of GSCM quality for attaining supply chain carbon transparency and accountability.

1. Introduction

The establishment of net-zero emission targets in >70 countries under the Paris Agreement (UN, 2023b) has led to a rapid expansion of corporate carbon accounting literature over the past decade (He et al., 2022). Accounting for 65% of global greenhouse gas emissions, carbon dioxide is the main source of anthropogenic greenhouse gases (EPA, 2023). Carbon accounting is defined as a system of processes for collecting, recording, and analysing carbon-related information to inform stakeholders' decision-making (Tang, 2017). Carbon accounting encompasses three scopes of carbon emissions. Scope 1 emissions are derived from sources directly controlled by the focal firm. Scope 2 emissions are derived from the focal firm's purchase and use of electricity, energy, and utilities. Scope 3 emissions are derived from upstream and downstream activities along the supply chain (NGER, 2023). The literature on carbon accounting mostly focuses on firm-specific Scopes 1 and 2 emissions rather than on firms' broader Scope 3 carbon footprint (Isil and Sebastianelli, 2020). As such, identified environmental governance initiatives are predominantly tacit on a firm's carbon footprint beyond its organizational boundaries (Downie and Stubbs, 2012).

Yet, it is crucial to shift our attention beyond firm-specific emissions and towards Scope 3 emissions. First, Scope 3 emissions account for more than five times those of Scopes 1 and 2 (CDP, 2020). Matthews et al. (2008) document that, on average, Scope 3 emissions comprise 84% of a firm's total carbon emissions. Moreover, Scope 3 emissions steadily increased by 84% between 1995 and 2015, compared to an increase of 47% and 78% in Scopes 1 and 2 emissions, respectively (Hertwich and Wood, 2018).[1] Second, international standard setters and regulators are increasingly focusing on firms' supply chain environments, as evidenced by emerging supply chain disclosure requirements. The US Securities and Exchange Commission proposed a climate disclosure rule in 2022 for US-listed firms to disclose supply chain climate-related risks in addition to all scopes of carbon emissions (S EC, 2022). Since commentators remain divided on the need to disclose Scope 3 emissions given the sophisticated nature of data collection and verification (SEC, 2024a, p. 223), the final rule implemented in 2024 eliminates Scope 3 disclosure requirements (SEC, 2024b). Nevertheless,

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[1] This is partly due to a perverse incentive for firms to outsource carbon-intensive processes to countries with lenient carbon regulations (Peters, 2010). Outsourcing reduces firm-specific emissions artificially by building an impression of improved carbon performance while merely shifting the ownership of emission sources. Hertwich and Wood (2018) document a rapid rise of Scope 3 emissions in developing countries with lenient carbon regulations.

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these requirements are still relevant for stakeholders' vigilance, as the states of California and New York mandate incoming Scope 3 emission disclosures through progressing state legislations (CSL, 2023; NY Senate, 2024). The dynamic nature of regulatory landscapes may also require US firms to report Scope 3 emissions under shifting federal requirements (Segal, 2023).

Beyond the US, global standard setters and regulators strive to implement harmonized climate and sustainability disclosure standards (ISSB, 2022). The International Financial Reporting Standards (IFRSs) sustainability disclosure framework is effective from 2024, subject to adoption by local jurisdictions (IFRS 2023).[2] Under these standards, eligible firms are required to disclose information related to their supply chain, along with all three scopes of carbon emissions. In 2022, the European Commission adopted the Directive for Corporate Sustainability Due Diligence in global supply chains, which establishes a due diligence duty for eligible entities to address negative environmental impacts in their global supply chain (EC, 2022).

Anecdotal evidence also indicates the rising importance of supply chain carbon accountability. In 2008, Hewlett-Packard (HP) did not address supply chain emissions despite being a leader in Scope 1 carbon management (HP 2009). In 2017, HP initiated the measurement of its Scope 3 emissions and announced a target to reduce these emissions by 10% by 2025 (HP 2023). By 2021, HP announced specific 2030 goals aimed at reducing emissions from its supply chain by 30%, product use by 30%, and end-of-service by 75% (HP 2022). This growing focus leads to a critical question: Do supply chain environmental interactions assist firms in complying with the emerging Scope 3 carbon disclosure and management requirements?

We examine green supply chain management (GSCM) as a crucial driver in achieving Scope 3 carbon objectives because firms do not operate in a vacuum and can exert influence over supply chain participants for their own sustainability needs (Burritt and Schaltegger, 2014). GSCM is defined as integrating environmental thinking into the management of supply chain relationships to obtain value enhancements (Sarkis et al., 2011; Christopher, 2022). Specifically, because supply chain participants' environmental responsibilities are increasingly economically important for a focal firm, a focal firm possesses incentives to manage the environmental responsibilities of these participants in addition to its own (Darendeli et al., 2022).

This study defines a focal firm's GSCM quality as the extent to which it integrates environmental objectives into the management of its supply chain relationships. The information processing theory highlights that changing operational environments create information processing needs that must be managed appropriately and effectively to address emerging uncertainties (Tushman and Nadler, 1978). As stakeholder attention on Scope 3 carbon accountability is nascent, notable barriers to Scope 3 carbon accounting and management include inadequate data availability and quality and a lack of associated knowledge and capabilities (Busch et al., 2022; Hettler and Graf-Vlachy, 2023). The resource dependence theory endorses that firms are unable to be self-sufficient in obtaining strategic information and capabilities to remain competitive and thus require collaboration with supply chain participants for long-run performance gains (Pfeffer and Salancik, 1978).

In our context, focal firms depend on their supply chain participants for carbon-related information and capabilities. As a result, focal firms interact with supply chain participants as part of their GSCM strategy to strengthen their supply chain relations. An accumulation of social capital subsequently fosters a mutual understanding of carbon objectives and facilitates the effective exchange of information and capabilities (Lee, 2015). Therefore, GSCM quality plays a critical role in the development and exchange of carbon-related information and capabilities in supply chains. We first conjecture that high-quality GSCM motivates focal firms' Scope 3 carbon disclosures through enhanced supply chain carbon information exchange. Then, we investigate whether GSCM quality strictly leads to ceremonial changes in carbon accountability in the form of Scope 3 carbon disclosures or if it leads to a reduction in Scope 3 emissions. The resource-based view contends that supply chain relational processes enhance the development and exchange of valuable capabilities along the supply chain for effective Scope 3 carbon management (Barney, 1991). For our second hypothesis, we conjecture that higher-quality GSCM leads to a reduction in focal firms' Scope 3 carbon footprint. Conversely, supply chain partners may be reluctant to genuinely commit to relationship-specific environmental responsibilities and investments due to potential hold-up risks (Schloetzer, 2012). Therefore, we test our conjectures using a sample of US-listed firms.

Scope 3 emission and supply chain disclosures under the shifting disclosure landscape in the US make it an appropriate and important research setting. US financial accounting standards require listed firms to disclose any major customers that account for 10% or more of their annual sales, which allows us to construct a measure of GSCM quality based on actual supply chain relationships. We construct two novel measures of GSCM quality. A supplier is compelled to conform to its major customer's integration of supply chain environmental objectives to preserve the business relationship (Wilhelm et al., 2016). Our first measure of GSCM quality is based on the top five suppliers' joint conformity to the focal customer's integration of environmental objectives into its supply chain, proxied using the suppliers' joint environmental performance. Our second measure of GSCM quality is based on eight indicators that assess a focal customer's internal GSCM protocols. Despite the global applicability of our measures, we focus on the US context because the identification of GSCM quality as a driver for Scope 3 disclosures will direct and strengthen the case for mandatory Scope 3 reporting in the US. The mandated disclosure of major customers by US-listed firms also allows us to objectively identify customer-supplier linkages to construct reliable GSCM quality measures. Importantly, our study addresses global concerns regarding Scope 3 emissions, as the principles of GSCM in improving relational trust and supplier environmental capabilities are not confined to a specific country. Further, US-based studies serve as benchmarks for other countries as they provide valuable insights into best practices, successful strategies, and effective policies (SBTI, 2018, p. 33).

Using both measures, we find that firms' higher quality of GSCM leads to (1) a higher likelihood of voluntary Scope 3 carbon disclosure and (2) a reduction in Scope 3 carbon footprint. Specifically, a one standard deviation increase in GSCM quality increases the likelihood of Scope 3 carbon disclosure by 28.76% and curbs the annual increase in Scope 3 carbon footprint by 20.92%. These findings affirm that the integration of environmental thinking into the management of supply chain relationships improves a firm's monitoring and management of its Scope 3 carbon footprint. Importantly, GSCM motivates both Scope 3 carbon transparency and accountability.

We conduct a host of endogeneity checks to ensure the robustness of our findings. First, we mitigate concerns surrounding self-selection on observables using the entropy balancing technique, which enhances the comparability of firms with below and above-sample median GSCM quality. Second, we use alternative measures of GSCM quality based on the top one and top three suppliers of the focal firm, which allows us to address relationship-specific heterogeneity and issues associated with asymmetric economic significance in the customer-supplier relationships. Third, we rule out alternative explanations that our results are driven by green suppliers selecting or being attracted to similarly green focal customers. Fourth, we conduct lead-lag and dynamic analysis to attenuate potential reverse causality concerns.

Fifth, we mitigate bias arising from simultaneity and dynamic endogeneity by using a Generalized Method of Moments (GMM) dynamic panel estimator. Sixth, we employ additional controls associated with supplier characteristics and the focal customer's environmental

[2] The two standards associated with sustainability disclosure are *IFRS S1 General Requirements for Disclosure of Sustainability-related Financial Information* and *IFRS S2 Climate-related Disclosures* (IFRS 2023).

governance to confirm the distinct effects of GSCM quality. Seventh, we mitigate the remaining omitted variable concerns using Oster (2019)'s tests of unobservable selection and coefficient stability. Eighth, we run a placebo simulation test using pseudo-customer-supplier relationships comprising of pseudo firms in the same industry and size tercile to rule out spurious effects. Finally, we follow Yahia et al. (2023) to employ a quasi-exogenous shock based on the availability of suppliers' environmental ratings. We find evidence that access to suppliers' environmental information, as facilitated by high-quality GSCM, is crucial for Scope 3 carbon accountability.

In channel analysis, we find that higher quality GSCM enhances relational trust between a focal customer and its suppliers and improves supplier environmental capabilities to reduce Scope 3 carbon footprint. This is consistent with the notion that higher quality GSCM improves inter-organizational information exchange. Specifically, enhanced relational trust promotes knowledge exchange and environmental collaboration with suppliers, while strengthened relational processes foster an information environment conducive to the development of supplier environmental innovation capabilities. This, in turn, promotes supply chain environmental efficiency to reduce Scope 3 carbon footprint. Supplementary analysis shows that the effect of GSCM quality in reducing Scope 3 carbon footprint is discernible when the focal customer shares durable relationships with its suppliers. This suggests that a supplier is inclined to make relationship-specific environmental investments for a longstanding customer.

Our study advances the literature in three ways. First, we provide an inter-organizational perspective on the environmental governance of firms. Recent empirical evidence suggests that corporate customers care about their suppliers' CSR in addition to their own (e.g., Dai et al., 2021b; Darendeli et al., 2022; She, 2022). Song et al. (2023) find that customers' signalling of their environmental commitment through environmental disclosures influences suppliers' engagement in emission abatement efforts. We deviate from these studies to conceptualize and collectively view corporate customers' environmental influence on supply chain partners as GSCM. Specifically, beyond the signalling effect of environmental disclosures, corporate customers influence environmental outcomes associated with supply chain partners by actively engaging and interacting with them under GSCM processes. Our findings highlight GSCM quality as an important component of corporate environmental governance.

Second, we emphasize that information exchange rooted in the supply chain management domain is pivotal for transitioning towards carbon accountability. The literature predominantly investigates the role of operational GSCM practices in reducing firm-specific carbon footprint (e.g., Elhedhli and Merrick, 2012; Xia et al., 2021). Survey-based studies find that GSCM practices improve environmental performance in the collective form of emissions, waste, and hazardous material consumption (e.g., Green et al., 2012; Laari et al., 2018; Al-Sheyadi et al., 2019). These studies focus on firm-specific outcomes and overlook the effect among a focal firm's supply chain network. Specifically, the effects of GSCM on supply chain carbon outcomes and from an informational perspective remain underexplored despite the fact that relational interactions are crucial for managing firms' broader carbon accountability (Bai et al., 2017). To this end, we diverge from prior literature by highlighting that GSCM promotes inter-organizational carbon information exchange for supply chain carbon accountability. Further, while individual operational practices including supplier selection and logistic decisions affect firms' carbon footprint, carbon reduction efforts are hampered by information gaps and limited supplier capabilities (Jira and Toffel, 2013). We highlight that these hurdles are mitigated through the collective enforcement of GSCM strategies.

Third, as prior GSCM studies examine carbon outcomes predominantly using a hypothetical modelling approach (Das and Jharkharia, 2018; Zhang et al., 2023), our empirical strategy based on panel data makes an essential contribution to the literature. Previous GSCM research also typically relied on surveys and questionnaires (e.g., Centobelli et al., 2021; Raut et al., 2021), which suffered from empirical challenges, including limited access to firms, self-report bias, response bias, and social desirability bias. As these approaches examine a static, cross-sectional relationship, they also provide a limited understanding of the dynamic effect of GSCM on corporate outcomes. To this end, we introduce two novel quantitative measures of GSCM quality designed for a panel dataset that can be utilized in a complementary fashion. These measures remain appropriate for cross-industry and cross-national contexts, thus addressing empirical issues associated with smaller sample sizes and limited generalizability in GSCM studies. Accordingly, we reshape future inquiry on GSCM by offering novel measures of GSCM quality. In contrast to surveys and questionnaires, the objective nature of the introduced measures based on actual supply chain relationships and third-party provided environmental ratings eliminate inconsistencies among subjectively determined measurement scales.[3]

Fourth, our focus on Scope 3 emission disclosures and performance extends the carbon accounting literature, which predominantly focuses on firm-specific Scopes 1 and 2 emissions. Prior environmental governance literature documents that environmental management systems (Ott et al., 2017), environmental management committees (Rankin et al., 2011; Peters and Romi, 2014), board environmental oversight (Bui et al., 2020), and named chief sustainability officers (Peters and Romi, 2014) motivate voluntary disclosure of firm-specific emissions. Another stream of studies documents the effect of board characteristics (Haque, 2017), sustainable compensation policy (Haque, 2017), corporate governance (Luo and Tang, 2021), ESG committee (Oyewo, 2023), and CSR reporting and assurance (Albitar et al., 2023) on firm-specific carbon footprint. Our focus on Scope 3 emissions rather than Scopes 1 or 2 emissions is both important and relevant because GSCM relates to processes in a focal firm's supply chain network rather than within its organizational boundary.

We extend the nascent stream of studies incorporating Scope 3 emissions in their consideration of carbon performance. Ellram et al. (2022) interview firms to gain an understanding of their dedication to managing freight transportation emissions, a source of Scope 3 emissions facing insufficient visibility. According to survey findings, reductions in Scope 3 emissions are primarily motivated by regulatory mandates (Xia and Cai, 2023). Hertwich and Wood (2018) provide an economy-wide industry breakdown of Scope 3 emissions using input-output analysis. A survey of firms in New Zealand reveals that of the entities reporting emissions, 73% are reporting some form of Scope 3 emissions (Ryan and Tiller, 2022). Hettler and Graf-Vlachy (2023) provide a review of the literature on Scope 3 reporting and highlight that quantitative studies based on large sample sizes will address issues associated with generalizability. Taken together, the emerging literature on Scope 3 emission accountability highlights the importance of identifying drivers of corporate Scope 3 carbon disclosure and management (Li et al., 2020). Given the global shift to Scope 3 carbon disclosure mandates, our study has timely practical implications for firms and policymakers seeking to improve supply chain carbon accountability.

The remainder of this paper is organized as follows. Section 2 provides the theoretical background and develops our hypotheses. Section 3 presents our sample selection and data, along with details on the construction of our measures. Section 4 presents the empirical results, including tests for robustness and economic channels and a cross-sectional test. Section 5 concludes.

2. Hypothesis development

The environmental governance literature documents that

[3] For example, Centobelli et al. (2021) segregate GSCM into the two dimensions of supply chain relationship management and sustainable supply chain design, while Raut et al. (2021)'s construct comprises of eco-design and environmental cost.

environmental management systems (Ott et al., 2017), environmental management committees (Rankin et al., 2011; Peters and Romi, 2014), board environmental oversight (Bui et al., 2020), and chief sustainability officers (Peters and Romi, 2014) motivate the voluntary disclosure of Scopes 1 and 2 emissions. However, it is important to consider Scope 3 emissions because of emerging supply chain disclosure mandates and increasing stakeholder attention to supply chain sustainability. The global value chains perspective asserts that the composition of products and services results from the efforts of multiple participants in the supply chain (Kogg and Mont, 2012). Intuitively, achieving Scope 3 carbon objectives relies on suppliers and customers in the focal firm's network (Burritt and Schaltegger, 2014). As focal firms lack knowledge of their supply chain footprint, engagement with supply chain partners becomes crucial to achieving supply chain carbon accountability (Hettler and Graf-Vlachy, 2023). The importance of engagement is emphasized through the high reliability of primary emissions data in comparison to estimations based on secondary factors (Downie and Stubbs, 2012; Busch et al., 2022).

Beyond the organizational boundaries of focal firms, suppliers possess valuable information concerning the environmental impacts of tangible and intangible products (Sarkis et al., 2011). Because a focal firm lacks direct access to this information, stronger interactions with suppliers enhance information flows and reduce information asymmetry (Chen et al., 2021). The management of supply chain interactions is encapsulated by supply chain management, which is defined by Christopher (2022) as the management of supply chain relationships to deliver superior value at less cost to the supply chain as a whole. A focal firm's upstream supply chain participants include manufacturers and suppliers, while its downstream participants include distributors, retailers, and customers (Schmidt et al., 2017).

Integrating environmental thinking into supply chain management is called GSCM (Sarkis et al., 2011). GSCM involves the collaborative planning of business processes, mutual exchange of information, cultivation of shared visions, and compatible corporate cultures aligned with environmental objectives (Cooper, 1993). This study defines a focal firm's GSCM quality as the extent to which it integrates environmental objectives into the management of its supply chain relationships. We conjecture that a higher quality of GSCM enhances carbon information exchange along a supply chain and thus affects a focal firm's Scope 3 disclosure and performance outcomes.

We illustrate how GSCM quality affects supply chain carbon information exchange through the aspects of green procurement, collaboration, supplier development, and reverse logistics (Srivastava, 2007). Green procurement entails the process of choosing green suppliers with a high level of environmental responsibility. As green suppliers possess the human, structural, and relational capital required for internal environmental management (Chuang and Huang, 2018), focal firms can obtain first-hand and high-quality carbon information from these suppliers. Interorganizational green collaboration in the form of joint product design and logistics coordination also enhances carbon information exchange (Gunasekaran et al., 2015).

Green supplier development involves training and supporting suppliers in their achievement of environmental objectives (Norheim-Hansen, 2023). Hosting supplier training programs brings suppliers and industry experts together and educates suppliers on emerging emission policies, environmental technologies, and best carbon management practices (Krause et al., 2007). This exchange of knowledge supports the accumulation of intellectual capital in relation to carbon monitoring and management and fosters an information environment conducive to the development of suppliers' environmental innovation capabilities (Wu, 2017).

Reverse logistics involves interacting with end consumers to collect and process used, unwanted, or damaged products and materials from end consumers for reuse, recycling, remanufacturing, or proper disposal (Carter and Ellram, 1998). It facilitates the acquisition of product lifecycle carbon information (Shi et al., 2012) and creates a knowledge reservoir supporting suppliers' environmental practices, as end consumer demands can be communicated upwards the supply chain (Wu, 2008). Taken together, higher-quality GSCM practices leverage supply chain relational interactions to enhance carbon information availability and quality for supply chain carbon accountability.

The information processing theory highlights that changing operational environments create information needs that must be managed appropriately and effectively to address emerging uncertainties (Tushman and Nadler, 1978). The nascent attention on supply chain carbon accountability is attributed to the inherent difficulty and complexity in measuring Scope 3 emissions (Busch, 2010). Insufficient data availability, comparability, consistency, and thus quality renders Scope 3 emissions accounting problematic (Busch et al., 2022). As such, effective carbon information exchange is required to address emerging uncertainties in supply chain carbon accountability.

According to resource dependence theory, interdependence and collaboration with supply chain participants are necessary for a focal firm to remain competitive (Pfeffer and Salancik, 1978) and to address arising uncertainties (Boyd, 1990). Firms require supply chain partnerships to effectuate long-run performance gains as they are not self-sufficient in obtaining strategic resources and capabilities for survival (Gavronski et al., 2011). Prior studies document the importance of interorganizational information and knowledge exchange for improvements in performance (Krause et al., 2007) and product quality (Primo and Amundson, 2002). Drees and Heugens (2013) imply that resource dependence theory explains firms' behaviour aimed at gaining social acceptance. In our context, a focal firm is reliant on its supply chain partners' carbon information and knowledge to achieve Scope 3 carbon objectives.

Focal firms, recognizing their dependence on supply chain partners, strengthen supply chain environmental interactions under GSCM to build relational trust and social capital (Nyaga et al., 2010). Social capital theory asserts that social relationships, trust, and collaboration with supply chain partners play a pivotal role in firm outcomes (Nahapiet, 1998). Strengthened relational trust and social capital facilitate effective carbon information exchange and support the implementation of supply chain carbon monitoring and evaluation processes. Upon enhanced access to carbon information and knowledge, firms are motivated to signal this informational advantage to stakeholders to gain a reputation in the marketplace, consensus from the institutional environment (Campbell, 2007), and stakeholder support (Zerbini, 2017). Therefore, we conjecture that higher-quality GSCM facilitates the exchange of supply chain carbon information, thus enabling firms to voluntarily disclose their Scope 3 carbon emissions under signalling motives. Our first hypothesis is as follows:

Hypothesis 1. Firms with higher quality green supply chain management are more likely to disclose Scope 3 carbon emissions.

Carbon disclosures may constitute firms' mere signalling for environmental legitimacy, especially as Scope 3 disclosures remain largely incomparable across firms (CDP, 2020, pp. 11–13). In our context, GSCM adopters may only make ceremonial changes through enhanced carbon information exchange rather than proactively manage their Scope 3 carbon footprint (Sarkis et al., 2011). If so, while higher GSCM quality may motivate Scope 3 carbon disclosures, it may not reflect underlying improvements in Scope 3 carbon footprint. We test this potential explanation by examining the effect of a focal firm's GSCM quality on its Scope 3 carbon footprint.

Prior studies identify a lack of knowledge and capabilities as the critical barrier to Scope 3 carbon management (Hettler and Graf-Vlachy, 2023). According to the resource-based view, a firm can sustain its competitive advantage by possessing rare, hard-to-imitate resources and capabilities, including information competencies and social capital (Barney, 1991; Skjoett-Larsen, 1999). Firms need to continuously integrate, build, and reconfigure their information competencies and social capital to achieve environmental objectives under changing operational environments (Teece et al., 1997). The intersection of resource dependence theory and the resource-based view involves firms identifying their resource needs and seeking external sources to fulfill these needs (Hillman et al., 2009). To effectively manage Scope 3 carbon emissions, a focal firm can improve its GSCM quality to access, develop, and integrate the external information and knowledge competencies of its supply chain partners (Takayabu et al., 2019).

Furthermore, supply chain collaboration under GSCM amplifies relational trust among supply chain members (Hoejmose et al., 2012). Strengthened relational trust enhances supply chain participants' willingness to share valuable information and knowledge in relation to supply chain carbon management, thus facilitating the development of difficult-to-imitate intellectual capital for carbon accountability (Allameh, 2018). Stronger relational trust also motivates environmental collaboration in the aspects of joint carbon planning and cooperative problem solving, which subsequently results in carbon performance improvements (Vachon and Klassen, 2008). Prior literature documents that GSCM practices improve firm-specific environmental performance, including Scopes 1 and 2 carbon footprint (e.g., Zhu and Sarkis, 2004; Feng et al., 2018; Laari et al., 2018). To this end, we deviate from these studies to explore whether and how GSCM quality affects a focal firm's broader Scope 3 carbon footprint. We extend the carbon accounting literature focusing on Scopes 1 and 2 emission performance (e.g., Haque, 2017; Luo and Tang, 2021; Albitar et al., 2023; Oyewo, 2023).

Our prediction that higher-quality GSCM reduces Scope 3 carbon footprint, however, is not without tension. Despite a focal firm's environmental requests under GSCM processes, its supplier may not genuinely conform to these requests. A supplier may perceive relationship-specific environmental investments to be too costly an of little personal benefit, especially if limited industry environmental benchmarks exist (Bai and Satir, 2020). Without clear incentives for suppliers to comply with the focal customer's relationship-specific requests, higher GSCM quality will not reduce its Scope 3 carbon footprint. Moreover, enhanced relational interactions increase asset specificity, defined as the degree to which investments are specific to a particular customer-supplier relationship and thus are of limited value beyond this relationship (Lui et al., 2009). High asset specificity increases hold-up risks, where focal customers renegotiate contract terms or switch to an alternative supplier after the supplier has made relationship-specific investments (Williamson, 1985; Lumineau et al., 2022). In response, a supplier may opportunistically reduce cooperation, withhold valuable carbon information, and shirk carbon responsibilities (Schloetzer, 2012).

Yet, we posit that GSCM quality remains potent for Scope 3 carbon footprint reduction. First, suppliers' incentives for conformity are solidified due to stakeholders' increasing demand for carbon accountability (Bayne et al., 2022). Suppliers are motivated to leverage customers' GSCM practices to obtain knowledge spillovers for their personal environmental performance improvements (Isaksson et al., 2016). Second, suppliers' opportunistic behaviour can be controlled and mitigated (Achrol and Gundlach, 1999). Unwilling to jeopardize their customer relationships, suppliers tend to reduce potential opportunism over time as relationship durability increases (Lumineau et al., 2022). Governance mechanisms such as relational trust and contracts for benefit sharing also mitigate risks of opportunism (Lui et al., 2009). Thus, we propose our second hypothesis:

Hypothesis 2. Firms' higher-quality green supply chain management reduces their Scope 3 carbon footprint.

3. Data and methodology

3.1. Sample selection and data

The debate on the future inclusion of mandatory Scope 3 emission disclosures under the climate disclosure rule of the US underscores the significance of identifying drivers of Scope 3 carbon accountability in the nation. Under the segment reporting section of US financial accounting standards, public firms are required to disclose the identity and associated information of any major customers that account for 10% or more of their annual sales.[4] We collect this disclosure data from the Compustat Segment files and compile a sample of customer-supplier-year observations with valid firm identifiers (GVKEY and CUSIP) for customers and their reported suppliers over the 2015–2022 period.[5] As utility providers fall under the realm of Scope 2 rather than Scope 3 emissions, we exclude observations where the supplier belongs to the utility industry (SIC codes 4000–5000).[6] A supplier may choose to voluntarily disclose a customer in their SEC filings even if sales made to the customer are under the 10% mandatory disclosure threshold (Cen et al., 2015; Chen et al., 2022). We retain customer-supplier relationships below this threshold, i.e., relationships that are voluntarily disclosed by the supplier. If a supplier voluntarily discloses a customer with desirable environmental performance, the act of suppliers' voluntary disclosure per se would not affect the customer's commitment to GSCM quality.[7] Rather, the inclusion of voluntarily disclosed relationships provides a clearer picture of a customer firm's application of GSCM quality to its broader supplier base. We exclude observations where the supplier's sales or the customer's cost of sales equals or is below zero.

Using this sample of customer-supplier-year observations, we construct a customer-year sample based on the top five disclosed suppliers retaining observations where the number of disclosed suppliers is less than five. We obtain financial information from Compustat annual files and firm-level environmental data from Refinitiv. We merge the data with our customer-year sample to form our final sample of 2850 customer-year observations covering 643 unique firms. Appendix A provides detailed definitions for the variables in our analyses. Panel A of Table 1 reports the sample selection process, and Panel B reports the sample distribution by industry.

3.2. Empirical model

To examine the relationship between GSCM quality and Scope 3 carbon outcomes, we estimate a panel fixed-effects model with robust standard errors, shown in eq. (1).

$$CarbonOutcomes_{i,t} = \alpha_0 + \beta_1 GSCMQuality_{i,t} + \sum \gamma_k Control_{,t} + \varepsilon_{i,t} \tag{1}$$

[4] Since 1976, the Statement of Financial Accounting Standards No. 14 (SFAS 14) required public entities to disclose major customers with an objective of allowing stakeholders assess the potential impact of changes in customer demand, preferences, and relationships on the firm's future performance (FASB, 1976). SFAS 14 was replaced by SFAS 131 in 1997 (FASB, 2008), which was subsequently superseded by Topic 280 of the Accounting Standards Codification (ASC) in 2009 (FASB).

[5] While Refinitiv offers coverage from 2002, data associated with Scope 3 carbon emissions only become relatively complete in 2015.

[6] Prior studies on supply chain material flows and innovation activity excluded suppliers in nonmanufacturing industries and logistics service providers, respectively (Potter and Paulraj, 2020; Wang et al., 2020). We include all industries in our main analyses as we focus on supply chain information flows and Scope 3 emissions, which are applicable across industries. In an untabulated sensitivity test, we exclude suppliers and customers in the financial and utility industries and find similar inferences.

[7] We conduct a robustness test to exclude voluntarily disclosed relationships i.e., observations where a supplier's annual sales to a disclosed customer are below the 10% threshold, and our findings remain consistent. This test also mitigates concerns that customer firms in our sample hold insufficient economic significance to their suppliers, despite that customer firms disclosed tend to hold more economic significance to their suppliers than vice versa(Chen et al., 2022). This is important because a customer must possess sufficient bargaining power over a supplier to enforce GSCM practices upon the supplier (Fabbri and Klapper, 2016).

Table 1
Sample selection.

Panel A: Sample for Study's Analysis	Observations
Preparation: Compile a set of customer-year sample observations with top suppliers identified based on Compustat Segments data from 2015 to 2022	5179
Step 1: Drop observations with missing values on the independent variable	(2271)
Step 2: Drop observations with missing values on the control variables	(57)
Final sample (customer-year observations)	2850
Number of unique firms	643

Panel B: Sample Distribution by Industry		
Industry	Number	%
Mining and construction	59	2.07
Textiles, printing, and publishing	117	4.11
Chemicals	87	3.05
Pharmaceuticals	223	7.82
Manufacturers	385	13.51
Computers	412	14.46
Transportation	194	6.81
Retail	564	19.79
Services	177	6.21
Other	632	22.18
Total	2850	100

Notes: This table presents the sample selection process and sample distribution by industry membership. Panel A reports the sample selection process. Panel B reports the industry membership of the final sample observations based on SIC codes as follows: mining and construction (1000–1999, excluding 1300–1399); textiles, printing, and publishing (2200–2799); chemicals (2800–2824, 2840–2899); pharmaceuticals (2830–2836); manufacturers (3000–3999, excluding 3570–3579 and 3670–3679); computers (7370–7379, 3570–3579, 3670–3679); transportation (4000–4899); retail (5000–5999); services (7000–8999, excluding 7370–7379); and other (000–0999, 9000–9999).

The dependent variable, *CarbonOutcomes,* refers to Scope 3 carbon disclosure (*Scope 3 Disclosure*) and Scope 3 carbon footprint (*Δ Scope3*) individually. Our independent variable of interest, *GSCMQuality*, is a customer firm's GSCM quality as measured by the *GSCM Score* and *GSCM Scale*.

We control for a series of firm-level characteristics. The first group of variables captures the financial and operational attributes of the customer firm. We control firm age (*Age*) since mature firms are likely to have established infrastructure for carbon management (de Villiers et al., 2011). We control the firm's size (*Size*) using the log-transformed value of total assets as larger firms are associated with greater commitment to carbon accountability (Cormier et al., 2005; Clarkson et al., 2008). We also control firm profitability using return on assets (*ROA*), as profitability may influence firms' carbon footprint (de Villiers et al., 2011).

Moreover, we control investment opportunities measured as the ratio of the market value to the book value of equity (*MTB*). Firms with better growth opportunities (higher market-to-book ratios) seek to reduce information asymmetry between internal management and external investors, which tends to be associated with greater environmental disclosures (Ben-Amar and McIlkenny, 2015). We control leverage (*Leverage*), as highly leveraged firms are more likely to prioritize financial performance over environmental commitments (Mishra and Modi, 2013; Haque, 2017). We control a firm's research and development intensity (*R&D Intensity*), as high R&D firms may be attributed to a higher input of natural resources and experimental processes (Churchill et al., 2019). We control the number of employees relative to total output (*Staff Intensity*), as the labour intensity of a firm can affect its Scope 3 emissions through environmental efficiencies (Huang et al., 2022). We control the level of cash constraints using net cash flows from operating activities scaled by total assets (*Cash Constraints*), as carbon management requires upfront capital (Alam et al., 2022).

The second group of variables is associated with the governance and environmental practices of the customer firm. We control board independence (*Board Indep*). An independent board tends to be more environmentally transparent and committed to carbon reduction initiatives (Haque, 2017). A dedicated environmental management team possesses key environmental capabilities valuable to carbon monitoring and performance (Bresciani et al., 2023). Therefore, we control whether the firm has an environmental management team (*Env Team*).

Carbon strategy directly influences firms' carbon outcomes (Luo and Tang, 2021). The inclusion of carbon issues in corporate policies signals the firm's proactive stance towards carbon management (Beckmann et al., 2014). Therefore, we control a firm's carbon emission policy (*Emission Policy*). We also control whether the firm is committed to publishing annual CSR reports (*CSR Report*), as firms committed to sustainability reporting are likely associated with carbon disclosure and management efforts. Lastly, we control whether the firm has an existing certified environmental management system (EMS) (*ISO or EMS*), as an EMS supports carbon accountability (Melnyk et al., 2003; Rankin et al., 2011). We include industry and year-fixed effects to control intertemporal and cross-industry variations. Our measures of GSCM quality are based on (1) annual industry percentile ranks of suppliers' environmental performance and (2) customers' internal GSCM protocols. Adding customer firm fixed effects potentially weakens our ability to capture the effect of customers' GSCM quality on their carbon outcomes, as the quality of GSCM can be sluggish, and firm fixed effects may absorb the effect of our analyses. All continuous variables are winsorized at the 1st and 99th percentiles to mitigate the influence of outliers.

3.3. Measures

3.3.1. GSCM quality

We define a focal firm's GSCM quality as the extent to which it integrates environmental objectives into the management of its supply chain relationships. A supplier is compelled to conform to its major customer's integration of supply chain environmental objectives to preserve the business relationship (Wilhelm et al., 2016). Our main measure of GSCM quality is based on suppliers' joint conformity to the focal customer's integration of environmental objectives into its supply chain, which is proxied using suppliers' joint environmental performance. Suppliers' environmental ratings are relevant for customer firms' internal assessment and evaluation of supplier environmental performance (Sardanelli et al., 2022). Therefore, we measure GSCM quality using the environmental score (*EnvScore*)[8] of a firm's top five suppliers.[9] For each customer firm *i*, we rank its supplier *j* based on economic importance, that is, the firm *i*'s total procurement (*Procurement*) from supplier *j* in year *t*. Using *EnvScore* and *Procurement* of the top five suppliers, we construct a novel firm-year measure of a customer firm *i*'s green supply chain management quality (*GSCM Score*). Specifically, *GSCM Score* is calculated as the sum of the procurement weighted *EnvScore* of each of the top five suppliers and is constructed as:

[8] Refinitiv's *EnvScore* is calculated through a percentile rank scoring methodology with value ranging from 0 to 100. The calculation of this score is based on a total of 68 metrics encompassing processes and outcomes related to the categories of resource use, emissions, and innovation. Category weights are adjusted for relevance to industry (Refinitiv 2022). As *EnvScore* is a percentile rank, it implicitly adjusts for time-induced heterogeneity in the metrics.

[9] The consideration of the top five suppliers rather than the top one supplier mitigates concerns that our measure of GSCM quality is driven by confounding supplier firm attributes.

$$GSCMScore_{i,t} = \sum_{j=1}^{n}\left(EnvScore \text{ of Supplier } j \; x \frac{\text{Firm } i\text{'s } Procurement \text{ from Supplier } j \text{ in year } t}{\text{Firm } i\text{'s total } Procurement \text{ from top } n \text{ suppliers in year } t}\right) \quad (2)$$

We first calculate the procurement ratio for each supplier *j*, which is the customer firm *i*'s procurement from supplier *j,* as a ratio of customer firm *i*'s total procurement from its top *n* suppliers. The integer *n* ranges from 1 to 5 depending on the number of reported suppliers and data restrictions.[10] Table OA.1 in the Online Appendix illustrates suppliers' inclusion in the *GSCM Score* calculation. Second, we multiply the procurement ratio by each supplier *j*'s *EnvScore* to obtain procurement-weighted *EnvScore* for each included supplier. Third, we sum up the procurement-weighted scores to form the final measure of the *GSCM Score*. Therefore, this measure captures both the environmental performance of the most important suppliers and the relative importance of each supplier to the focal firm.

To supplement our main measure, we construct an alternative GSCM quality measure (*GSCM Scale*) using eight indicators assessing a customer firm's internal GSCM protocols based on Refinitiv data. This measure reflects the extent to which a focal customer integrates environmental objectives into the management of its supply chain relationships. We detail the construct of *GSCM Scale* in Table OA.2 in the Online Appendix.

3.3.2. *Scope 3 carbon outcomes*

3.3.2.1. Scope 3 carbon disclosure. We obtain firms' voluntary Scope 3 carbon disclosure information from Refinitiv, where information is collected from publicly available sources, including company websites, annual reports, and CSR reports (Refinitiv, 2023a). We create an indicator variable (*Scope 3 Disclosure*) equal to one if a firm reports Scope 3 emissions in addition to Scope 1 or Scope 2 emissions and equal to zero if the firm only reports Scopes 1 or 2 emissions. It is important to assign the values accurately based on firms' self-disclosure rather than vendor-provided estimates. Thus, we examine two Refinitiv data points documenting the source for upstream and downstream Scope 3 emissions, and we only assign the value of one if either upstream or downstream Scope 3 emissions are labelled as self-reported.[11]

3.3.2.2. Scope 3 carbon footprint. To attenuate endogeneity concerns, we measure Scope 3 carbon footprint using the change in total Scope 3 carbon emissions (from $t+1$ to $t+2$) as a ratio of the base year ($t+1$). Following prior literature (e.g., Luo et al., 2023), we adopt an alternative measure using the change in total Scope 3 carbon emissions scaled by total sales.[12] Scaled emissions take into account changes in the output level to produce more appropriate comparisons across firms and years (Hoffman, 2007). Our Scope 3 carbon footprint measures are based on estimated emissions[13] in Refinitiv, as most firms self-report solely upstream or downstream Scope 3 emissions rather than both, which results in comparability issues. We further control stock returns for analyses on Scope 3 carbon footprint, as prior literature documents a positive association between unscaled vendor-estimated carbon emission and stock returns (Aswani et al., 2023).

4. Empirical results

4.1. *Descriptive statistics*

Fig. OA.1 in the Online Appendix illustrates that the percentage of firms voluntarily disclosing Scope 3 carbon information is increasing over our sample period. Table OA.3 describes the disclosure sources of Scope 3 carbon emissions information. One explanation for the relative prevalence of upstream emissions reporting compared to downstream emissions reporting is that the measurement of downstream emissions is more complex and requires sophisticated GSCM capabilities beyond customer collaborations (Isil and Sebastianelli, 2020). In contrast, a firm

Table 2
Descriptive statistics.

Variable	N	Mean	Median	SD	Q1	Q3
Scope 3 Disclosure	1889	0.64	1.00	0.48	0.00	1.00
Δ Scope3	1645	0.73	0.16	2.62	−0.01	0.47
Δ Scope3/Sales	1645	0.55	0.12	2.16	−0.03	0.33
GSCM Score	1652	30.90	25.28	26.15	7.19	51.45
GSCM Scale	2850	3.20	4.00	2.10	1.00	5.00
Age	2850	16.93	18.00	4.69	16.00	20.00
Size	2850	23.19	23.25	1.59	22.11	24.33
ROA	2850	0.03	0.04	0.14	0.01	0.08
MTB	2850	1.52	0.99	1.69	0.55	1.80
Leverage	2850	0.84	0.88	4.27	0.41	1.49
R&D Intensity	2850	0.23	0.02	1.53	0.00	0.06
Staff Intensity	2850	3.92	2.43	12.00	1.24	3.94
Cash Constraints	2850	0.09	0.09	0.11	0.05	0.13
Env Team	2850	0.55	1.00	0.50	0.00	1.00
Emission Policy	2850	49.47	64.06	32.98	0.00	73.13
Board Indep	2850	0.82	0.86	0.12	0.78	0.91
CSR Report	2850	0.65	1.00	0.48	0.00	1.00
ISO or EMS	2850	0.35	0.00	0.51	0.00	1.00
Stock Returns	2218	6.08	2.13	22.24	−3.73	14.55
Trade Credit Financing	2844	0.09	0.05	0.11	0.02	0.11
Supplier Env Innovation	2145	22.96	20.68	24.33	0.00	35.64
Ave Rel Durability	2848	6.31	5.00	4.55	3.00	9.00

Notes: This table presents the descriptive statistics of variables, including the number of observations (*N*), mean, median, standard deviation, and quartile (25% and 75%). Details on variable definitions are in Appendix A.

[10] For the Scope 3 carbon disclosure model, observations for each value of *n* are as follows: $n=1$ (405 obs.), $n=2$ (263 obs.), $n=3$ (195 obs.), $n=4$ (186 obs.), $n=5$ (78 obs.). 65 out of 405 obs. For $n=1$ is based on a supplier other than the first-ranked supplier.For the Scope 3 carbon footprint model: $n=1$ (387 obs.), $n=2$ (246 obs.), $n=3$ (181 obs.), $n=4$ (133 obs.), $n=5$ (37 obs.). 71 out of 387 obs. For $n=1$ is based on a supplier other than the first-ranked supplier.

[11] In fallback sequence, Refinitiv obtains Scope 3 emission numbers or estimates using: (1) self-reported values by firms, (2) winsorized values for extreme data points, (3) extrapolated values from previous years, (4) fossil fuel production model for downstream emissions in applicable industries, and (5) aggregated model combining sector median and linear regressions (Refinitiv, 2023b). For descriptive statistics relating to our sample, see Table OA.3 in the Online Appendix.

[12] There may be concerns that firms' total Scope 3 carbon emissions are subject to a trend of understatement due to data limitations. This understatement makes our inferences stronger, as we continue to find significant results within only an identified proportion of firms' Scope 3 carbon footprint.

[13] Our results remain consistent if we only include observations where upstream *or* downstream emissions are self-reported. Moreover, our results are not driven by estimation procedures, as we do not observe significant results using only vendor-estimated upstream *and* downstream emissions based on aggregate models.

Table 3
Green supply chain management and Scope 3 carbon disclosures.

	Dependent variable: *Scope 3 Disclosure*	
	Model 1:	Model 2:
GSCM Score	0.011***	
	(3.578)	
GSCM Scale		0.183***
		(5.919)
Age	−0.012	−0.020
	(−0.576)	(−1.159)
Size	0.234***	0.305***
	(3.106)	(4.739)
ROA	−0.744	−0.964
	(−0.485)	(−0.777)
MTB	0.136*	0.233***
	(1.683)	(3.077)
Leverage	−0.012	−0.003
	(−0.669)	(−0.204)
R&D Intensity	−0.150	0.365
	(−0.176)	(0.352)
Staff Intensity	−0.022	−0.027
	(−0.876)	(−1.359)
Cash Constraints	1.067	−1.007
	(0.646)	(−0.742)
Env Team	0.690***	0.210
	(3.618)	(1.418)
Emission Policy	0.005	0.003
	(1.225)	(0.941)
Board Indep	1.346	0.129
	(1.577)	(0.203)
CSR Report	0.692**	0.388*
	(2.385)	(1.663)
ISO or EMS	0.002	0.156
	(0.014)	(1.216)
Constant	−9.360***	−9.720***
	(−4.932)	(−5.924)
Customer Industry FE	Yes	Yes
Year FE	Yes	Yes
Observations	1127	1626
Pseudo R^2	0.198	0.194

Notes: This table presents the logistic regression results on the effect of GSCM quality on the likelihood of Scope 3 carbon disclosure. Details on variable definitions are in Appendix A. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Robust t-statistics are reported in parentheses.

can often demand its suppliers to provide detailed carbon information related to its procurement. We present the descriptive statistics for our variables in Table 2.[14]

With a range of values from 0 to 100, the mean of the *GSCM Score* is 30.90. The values for the *GSCM Scale* range from 0 to 8 and have a mean of 3.20. This suggests that focal firms' GSCM quality is prone to further improvements. In our sample, 4% of observations disclose only Scope 1 carbon emissions, 32% disclose both Scopes 1 and 2 carbon emissions, while 64% disclose some form of Scope 3 carbon emissions (i.e., upstream, downstream, or both) in addition to Scopes 1 and 2 emissions. On average, the annual increase in Scope 3 carbon footprint is at 73% for absolute emissions and 55% for emissions scaled by total sales. This suggests that accounting for Scope 3 carbon emissions is important to meaningfully achieve carbon objectives.

4.2. Green supply chain management quality and Scope 3 carbon disclosure

We first test whether GSCM quality affects the likelihood of voluntary Scope 3 carbon disclosure using a logistic model. We present the results in Table 3. As predicted in H1, we find that a higher quality of

[14] Across our baseline models, we compute the variance inflation factor (VIF) for all explanatory variables to detect potential multicollinearity issues. All VIF values are below 5 and the mean VIF value in each model approximates to 2.

Table 4
Green supply chain management and Scope 3 carbon footprint.

	Model 1: *Δ Scope3*	Model 2: *Δ Scope3/Sales*	Model 3: *Δ Scope3*	Model 4: *Δ Scope3/Sales*
GSCM Score	−0.008***	−0.007***		
	(−2.595)	(−2.707)		
GSCM Scale			−0.074*	−0.065*
			(−1.830)	(−1.846)
Stock Returns	−0.002	−0.003	0.000	−0.001
	(−0.635)	(−1.106)	(0.141)	(−0.265)
Age	−0.038*	−0.009	0.003	−0.002
	(−1.652)	(−0.595)	(0.234)	(−0.142)
Size	−0.127	−0.071	−0.122*	−0.088
	(−1.581)	(−1.076)	(−1.831)	(−1.526)
ROA	3.900**	−0.625	0.921	0.982
	(2.168)	(−0.715)	(1.376)	(1.644)
MTB	0.073	−0.010	−0.014	−0.051
	(1.139)	(−0.381)	(−0.334)	(−1.457)
Leverage	0.030**	0.026*	0.024*	0.024**
	(2.193)	(1.936)	(1.836)	(2.089)
R&D Intensity	0.257	0.115*	0.918	0.921
	(1.040)	(1.651)	(1.170)	(1.372)
Staff Intensity	−0.013	−0.016*	−0.032	−0.013
	(−0.591)	(−1.945)	(−1.612)	(−0.734)
Cash Constraints	−5.265	0.426	0.072	0.201
	(−1.645)	(0.543)	(0.057)	(0.186)
Env Team	0.327**	0.275**	0.379**	0.314**
	(2.376)	(2.327)	(2.187)	(2.077)
Emission Policy	0.002	0.002*	0.003	0.003
	(1.324)	(1.733)	(1.177)	(1.329)
Board Indep	0.013	0.087	0.508	0.581*
	(0.025)	(0.225)	(1.330)	(1.695)
CSR Report	0.391**	0.336**	0.463**	0.473**
	(2.112)	(2.236)	(2.020)	(2.434)
ISO or EMS	0.066	0.101	0.003	0.068
	(0.276)	(0.484)	(0.011)	(0.348)
Constant	3.495*	1.248	1.992	1.128
	(1.669)	(0.789)	(1.305)	(0.842)
Customer Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	984	984	1357	1357
Adjusted R^2	0.057	0.015	0.017	0.018

Notes: This table presents the results on the effect of GSCM quality on Scope 3 carbon footprint. Scope 3 carbon footprint is measured using year-on-year change in Scope 3 carbon emissions (*Δ Scope3*) and the year-on-year change in Scope 3 carbon emissions scaled by total sales (*Δ Scope3/Sales*). Details on variable definitions are in Appendix A. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Robust t-statistics are reported in parentheses.

GSCM results in a greater likelihood of Scope 3 carbon disclosure using both measures of GSCM quality (Model 1, *t-statistic* = 3.58, $p < 0.01$; Model 2, *t-statistic* = 5.92, $p < 0.01$). Specifically, a one standard deviation increase in GSCM quality increases the likelihood of Scope 3 carbon disclosure by 28.76%.[15]

Turning to the control variables, larger firms are associated with a greater likelihood of Scope 3 carbon disclosures due to enhanced visibility (Cormier et al., 2005). Firms with better growth opportunities (higher market-to-book ratio) tend to utilize carbon disclosures to reduce information asymmetry (Ben-Amar and McIlkenny, 2015). A dedicated environmental management team indicates commitment towards carbon disclosures (Bresciani et al., 2023), while an existing commitment to sustainability reporting likely reflects carbon monitoring commitments. Overall, our results confirm that a higher quality of focal firms' GSCM enhances supply chain carbon information exchange for Scope 3 carbon disclosures. In congruence with 'you can't improve

[15] For economic significance, we multiply the coefficient of *GSCM Score* by its standard deviation of 26.15 across all analyses.

what you don't measure' (Drucker, 2018), the measurement and monitoring of Scope 3 carbon footprint under high-quality GSCM form an important steppingstone for carbon management and reduction.

4.3. Green supply chain management quality and Scope 3 carbon footprint

We then investigate whether a higher quality of GSCM improves Scope 3 carbon accountability beyond those of voluntary disclosures. We present the results in Table 4. As predicted in H2, we find that a higher quality of GSCM leads to a reduction in Scope 3 carbon footprint using both measures of GSCM quality. We find consistent results across both the year-on-year change in absolute Scope 3 carbon footprint (Model 1, *t-statistic* $= -2.60$, $p < 0.05$; Model 3, *t-statistic* $= -1.83$, $p < 0.10$) and Scope 3 carbon footprint scaled by total sales (Model 2, *t-statistic* $= -2.71$, $p < 0.01$; Model 4, *t-statistic* $= -1.85$, $p < 0.10$). In economic terms, a one standard deviation increase in GSCM quality curbs the annual rise in Scope 3 carbon footprint by 20.92%.

Consistent with the literature, highly leveraged firms prioritize financial performance over environmental performance and thus have a larger Scope 3 carbon footprint (Mishra and Modi, 2013). Interestingly, an environmental team is associated with a higher likelihood of Scope 3 carbon disclosures but a greater annual rise in Scope 3 carbon footprint, potentially due to a focus on managing firm-specific emissions. Firms with CSR reporting commitments are associated with a greater Scope 3 carbon footprint, highlighting that CSR reporting is not adequate to achieve supply chain carbon accountability. Overall, the results suggest that enhanced GSCM quality delivers benefits beyond those of an informational nature and is an important consideration for supply chain carbon accountability. We explore the channels through which higher-quality GSCM reduces Scope 3 carbon footprint in Section 4.5.

4.4. Addressing endogeneity

4.4.1. Self-selection bias

GSCM activities can be nonrandom and reflect underlying firm attributes that also affect Scope 3 carbon outcomes. We address this concern about self-selection bias using a quasi-matching method to reduce misspecification of the functional form underlying the relation between the variable of interest and the given outcome (Hainmueller, 2012). A matched sample assumes selection on the observables and weights each observation such that post-weighting distributional properties of treatment and control observations are identical, thus achieving covariate balance and reducing model dependence in the subsequent analyses (Wilde, 2017).

We partition our observations into groups of low GSCM quality (*GSCM Score* Indicator $= 0$) and high GSCM quality (*GSCM Score* Indicator $= 1$) based on the sample mean of the *GSCM Score*. To mitigate concerns that the differences in observable firm attributes drive our results, we implement an entropy balancing technique to achieve covariate balance across the high-order moments of covariate distributions between the two groups (Bonsall and Miller, 2017). Rather than discarding unmatched units, entropy balancing allows us to retain larger samples by allowing observation weights to vary smoothly in satisfying the covariate balance conditions (Wilde, 2017).

Table OA.4 in the Online Appendix reports the covariate balance pre- and post-entropy balancing on our standard set of controls. Panel A presents summary statistics of the covariates before entropy balancing, which is a naïve comparison of attributes between firms with low and high GSCM quality. Observed firm attributes are significantly different across the two groups. After entropy balancing (Panel B), we find that all covariates' mean, variance, and standard deviation are nearly identical across the two groups. We apply entropy balancing weights to our models (Scope 3 carbon disclosures and Scope 3 carbon footprint) separately, as each model contains different covariates. We re-estimate these models using entropy-balanced samples and find that the results from both models, as reported in Table OA.5 in the Online Appendix, continue to be consistent with our baseline findings.

4.4.2. Potential confounding factors and alternative measures of GSCM quality

To mitigate concerns that the selection of the top five suppliers as the basis for the *GSCM Score* is arbitrary, we use an alternative measure of GSCM quality based on the top three suppliers. Specifically, we construct the *Top 3 GSCM Score* calculated as the sum of the procurement-weighted *EnvScore* of each of the top three suppliers. We rerun our baseline analyses using the *Top 3 GSCM Score* and report the results in columns (1) and (3) of Table OA.6 in the Online Appendix. Results remain consistent and thus provide robustness to our main measure of the *GSCM Score*.

Further, as our main measure of GSCM quality (*GSCM Score*) is based on the top five suppliers for a more accurate representation of the customer's GSCM practices, it does not allow us to account for heterogeneity associated with individual customer-supplier relationships. While we utilize a supplementary measure of GSCM quality (*GSCM Scale*) based on customers' internal GSCM protocols across our baseline analyses, there may be remaining concerns about measurement noise associated with the *GSCM Score*. Specifically, a supplier must disclose its customer's identity if 10% or more of revenue is derived from that customer. However, a customer firm is not required to disclose its major suppliers. Therefore, customer firms tend to be of greater magnitude and hold more economic significance to their suppliers than vice versa (Chen et al., 2022). In our baseline analyses, we assume that the top five suppliers hold sufficient significance for a customer firm and, thus, are appropriately identified to be the target of the customer firm's GSCM protocols. Yet, asymmetric economic significance may raise concerns regarding measurement validity.

Therefore, we rerun our analyses using the top one supplier's *EnvScore* (*Top 1 GSCM Score*) to observe the effects of relationship-specific heterogeneity and address potential measurement errors. This allows us to additionally control supplier industry fixed effects, along with the durability (*Rel Durability*) and economic importance (*Procurement*) of the customer-supplier relationship.[16] Moreover, we only retain observations where the top one supplier is sufficiently important to the customer firm. We use the ratio of the customer firm's total procurement from a supplier (*Procurement*) to the customer's total cost of sales (*Cost of Sales*) during the year to ascertain a supplier's importance to the customer. We classify a supplier as important to the customer if this ratio is above 0.5%.[17] We rerun our baseline analyses using the *Top 1 GSCM Score* and a sample of important suppliers and report the results in columns (2) and (4) of Table OA.6 in the Online Appendix. The results support our main findings.

4.4.3. Alternative explanations

One possible explanation for our findings is that greener suppliers may strategically choose customers with a higher level of environmental management. It may also be that a green focal firm's environmental management strategy attracts green suppliers to cooperate with it. These scenarios imply that the *GSCM Score* does not necessarily reflect a focal firm's active green management of its supply chain. Rather, the construct of the *GSCM Score* based on suppliers' environmental ratings may incorporate confounding influences, whereby the ratings fail to

[16] If a customer-supplier relationship terminates in a year but is reinstated in a future year within our sample period, we assume that the relationship does not genuinely terminate, as relationship-specific attributes and influences are likely to persist.

[17] The mean cost of sales for customer firms in our sample is \$10 billion and 0.5% of \$10 billion is \$50 million. As cost of sales include other labour and overhead costs, this ratio understates the true importance of each supplier to the customer.

capture a focal firm's influence on its suppliers. We rule out this potential explanation using theoretical and empirical reasoning.

First, for greener suppliers to select similarly greener customers, they must possess the discretion to do so. The concern that relationships are formed and terminated according to the suppliers' discretion rather than to the customer's choice is mitigated by the size difference observed between suppliers and customers. On average, the total asset value for a supplier is around $6 billion USD, while the average total asset value of a focal customer firm is around $32 billion USD. It is unlikely that smaller suppliers possess significant discretion in choosing which large firms to transact with. Using CSR ratings, Dai et al. (2021b) document a unilateral effect on CSR only from customers to suppliers. They suggest that it is the customer that selects and subsequently influences supplier CSR behaviour, rather than vice versa. Taken together, we expect that a customer predominantly possesses the discretion to select suppliers and manage their environmental performance, which comprises its GSCM strategy.

Second, if a focal firm actively manages its supply chain according to its GSCM strategy, we expect more durable contractual relationships with its suppliers to result in improvements in its GSCM quality. Accordingly, if the *GSCM Score* accurately captures GSCM quality, we expect a positive relationship between relationship durability (Ave *Rel Durability*) and the *GSCM Score*. The duration of a relationship reflects the level of commitment a focal firm makes to influence its supplier's decisions and operations in the form of relationship-specific investments (Joskow, 1987; Birnberg, 1998). A durable relationship enhances cooperation (Caglio and Ditillo, 2008), broadens relational scope (Seshadri and Mishra, 2004), and facilitates collaborative performance management practices (Dekker et al., 2016). On the other hand, if *GSCM Score* does not reflect a focal firm's active GSCM and instead is a result of suppliers strategically choosing their customers, we expect no significant relation between Ave *Rel Durability* and *GSCM Score*. That is, relationship durability should not affect a supplier's choice in selecting customers based on its environmental preferences. We test this by regressing lead *GSCM Score* on lagged Ave *Rel Durability*. We include the same set of controls as in our baseline analyses. Table OA.7 in the Online Appendix reports the findings. We find that relationship durability has a positive impact on *GSCM Score* at the 1% level. This suggests that *GSCM Score* captures a focal firm's active GSCM and does not merely reflect green suppliers' choice to choose similarly green customers.

Third, while the above discussion mitigates the possibility that our findings are driven by suppliers choosing customers, there remains a possible explanation that green customers attract equally green suppliers. If such, our findings are driven by the focal firm's attractiveness rather than its active management of its suppliers. To ascertain that the *GSCM Score* accurately captures active management rather than attractiveness, we observe the correlation between the *GSCM Score* and the *GSCM Scale*. The *GSCM Scale* is based on eight indicators directly capturing a focal firm's GSCM practices and thus reflects its active GSCM practices. Thus, if the *GSCM Score* similarly captures GSCM practices, we expect a positive association between the two constructs. We find that the correlation coefficient between the *GSCM Score* and the *GSCM Scale* is 0.227, which is significant at the 1% level (*p-value* = 0.000). This provides evidence that the *GSCM Score* is an appropriate indicator of a firm's GSCM quality and that our findings are not driven by the focal firm's attractiveness to its suppliers.

4.4.4. *Reverse causality*

Although reverse causality issues are partially mitigated due to the voluntary nature of Scope 3 carbon disclosures, we attenuate potential reverse causality concerns using a lead-lag approach. We use the one-year lagged independent variable and one-year lead dependent variable to rerun our analyses. We report the results in Table OA.8 in the Online Appendix and find inferences consistent with our baseline results. Moreover, we find that the effect of GSCM quality on Scope 3 carbon outcomes persists for up to three years ($t + 3$), as reported in Table OA.9. This highlights that improved carbon information exchange facilitated by GSCM practices delivers long-term benefits for a focal firm.

4.4.5. *GMM estimation*

The cause-and-effect relationship between GSCM quality and Scope 3 carbon outcomes may be generally dynamic over time. For example, the previous year's carbon outcomes could be driving the current-year effect of GSCM quality on Scope 3 carbon outcomes. To address this potential concern, we perform a GMM estimation to obtain consistent results in the presence of unobserved heterogeneity, simultaneity, and dynamic endogeneity (Arellano and Bond, 1991; Ullah et al., 2018).

We utilize a one-step system GMM dynamic panel estimator (Roodman, 2009) and assume that all instruments are correlated with past errors, such that they are predetermined and not strictly exogenous (i.e., they are weakly exogenous). Following Arellano and Bover (1995), we use the past values of all our independent variables as instrumental variables, as prior literature documents that using the historical values of independent variables is the best way to control for endogeneity (Bazzi and Clemens, 2013). Our results, as shown in Table OA.10 in the Online Appendix, indicate that our key conclusions remain valid. In economic terms, we find that, when controlling for endogeneity, a one standard deviation increase in GSCM quality increases the likelihood of Scope 3 carbon disclosure by 13.08% and curbs the annual rise in Scope 3 carbon footprint by 28.77%. The reduction effect on Scope 3 carbon footprint is of a greater magnitude than our baseline findings.

The use of lagged values as instruments necessitates that the error term does not exhibit second-order serial correlation (Arellano and Bond, 1991). The Arellano-Bond test indicates that the second-order serial correlation for AR (2) in first differences is insignificant across both models ($p = 0.377$ for Scope 3 carbon disclosure and $p = 0.604$ for Scope 3 carbon footprint). There are no weak instrument validity issues in our GMM estimation, as the lagged dependent variable(s) coefficient in our benchmark estimations is significantly lower than 0.9. Nonetheless, we run the Hansen's J test, which suggests that although weakened by many instruments, our models are robust and do not have an overidentification issue. Furthermore, the difference-in-Hansen test indicates that there is insufficient evidence to reject the null of instrument exogeneity ($p = 0.318$ for Scope 3 carbon disclosure and $p = 0.680$ for Scope 3 carbon footprint). Overall, these test results show that our instrumentation is strong and valid.

4.4.6. *Additional controls*

To account for the potential confounding influence of supplier-specific characteristics, we disaggregate our sample into individual customer-supplier relationships. In doing so, we replace the independent variable of interest *GSCM Score* with *Supplier Env Score*, which is the environmental rating of the supplier in the respective relationship. Dai et al. (2021b) use CSR ratings to document that a customer's CSR rating has unilateral implications on the rating of its individual suppliers. Building on their findings, the *Supplier Env Score* is a feasible reflection of the GSCM influence of a focal customer on the respective supplier. We incorporate additional supplier-level controls identical to those of the focal firm. However, we exclude supplier-level controls related to a supplier's environmental commitment and objectives to mitigate collinearity. The results are reported in Table OA.11 in the Online Appendix. We find that our results remain robust in this disaggregated sample with supplier-level controls.[18]

Furthermore, we employ additional controls across our baseline analyses to address potential omitted variable concerns and to ensure the effects of GSCM quality form distinct aspects of environmental governance. The variable construction of additional controls is detailed in Appendix A. We control for the overall quality of corporate governance mechanisms (*GovScore*), whether the firm has an existing CSR committee (*CSR committee*), whether the firm trains its employees on environmental issues (*Env Train*), and the firm's CSR strategy score (*CSR Strategy*). We also control Scope 1 carbon emission intensity (*Scope1/Sales*) and Scope 2 carbon emission intensity (*Scope2/Sales*) to observe the potential effects of production outsourcing where the associated emissions will convert from direct emissions to Scope 3. We report the results in Table OA.12 in the Online Appendix. We find results consistent with our baseline findings, which confirm that GSCM quality forms distinct and important aspects of corporate environmental responsibility.

4.4.7. Omitted variables

To the extent that observed controls do not fully capture firm-specific heterogeneity, omitted variable concerns may persist. Following Oster (2019), we assess unobservable selection and coefficient stability to assess the sensitivity of the results to unobservable heterogeneity. The test results are reported in Table OA.13 in the Online Appendix. β^* is the coefficient of interest, which is the coefficient on the *GSCM Score* in our context. Specifically, we estimate (1) bias-adjusted coefficient β^* using delta (δ) and R^2_{max}, and (2) δ, which is defined as the bias arising from the unobservables relative to the bias from observable controls. δ is calculated based on the changes in β^* and the R^2 values for regression with and without observable controls.

For the first test, we set the parameters such that $R^2_{max} = 1.3 \times R^2$ of the baseline results with controls and $\delta = 1$, as recommended by Oster (2019). A value of $\delta = 1$ indicates that the observables are at least as important as the unobservables and, thus, is an appropriate cut-off (Oster, 2019). We obtain the value of coefficient estimate β^*, which is reported in the top row of each panel in the table. If β^* is within the 95% confidence interval of the original linear estimates for each of the carbon outcome models, then the baseline results are robust and are unlikely to contain an omitted variable bias. For the second test, we set the parameters $\beta^* = 0$, and R^2_{max} remains the same as the previous test. We obtain the value of δ, which is reported in the bottom row of each panel. If δ is below -1 or above 1, our baseline results are robust and unlikely to contain an omitted variable bias. Specifically, for unobservables to overturn our result and produce a zero coefficient on the *GSCM Score*, they would need to be δ times (2.77 times for Scope 3 carbon disclosures and 13.19 times for Scope 3 carbon footprint) as important as the observables. Therefore, the test results indicate that our results are robust and are unlikely to be subject to omitted variable concerns.

4.4.8. Placebo tests

We run a placebo simulation test to rule out potential co-movement between similarly sized firms in the same industry. We generate a simulated sample by replacing the actual customer firm in a relationship pair with a randomly chosen 'pseudo' firm in its own industry and size tercile. We repeat this procedure 1000 times and generate 1000 sets of coefficients based on the same regression specifications of the true sample. We only break down the actual customer-supplier relationships, and the pseudo-customer firm maintains the industry-level and other firm-level characteristics of the true customer firm. As such, if economic dynamics at these levels drive our results, we expect to see no difference between the pseudo-estimated coefficients and coefficients from the true sample. In other words, if we do observe that the coefficient from the true sample is larger, our baseline results are attributed only to actual customer-supplier relationships.

We plot the true coefficients and the distribution of pseudo-estimated coefficients in the Online Appendix, Fig. OA.2. For the Scope 3 carbon disclosure model (Panel A), the pseudo-coefficients of *GSCM Score* from simulated samples have a near-zero mean (−0.0001) and are much smaller in magnitude than the true coefficient (0.011). Similarly, the pseudo-coefficients for the Scope 3 carbon footprint model (Panel B) have a near-zero mean (−0.0002) and are much smaller in magnitude than the true coefficient (−0.0079). These results suggest that our findings are not driven by spurious effects.

4.4.9. Quasi-exogenous shock: Ratings availability

To further mitigate endogeneity concerns, we follow prior studies (Cheng et al., 2014; Yahia et al., 2023) to employ an exogenous shock to a customer firm's Scope 3 carbon accountability. Chatterji and Toffel (2010) find that when a rating agency expands its CSR rating coverage to a firm that it had not previously rated, both the firm itself and its investors exhibit responses to the newly introduced rating. We conjecture that the expansion of environmental rating coverage for the suppliers of a customer firm allows the customer firm to better account for its Scope 3 emissions. Darendeli et al. (2022) identify that the expansion of CSR rating coverage for suppliers represents an incremental, salient information shock that informs corporate customers about their suppliers' CSR.

Intuitively, if the availability of ratings allows a customer firm to gain incremental information regarding its suppliers' environmental performance, then an exogenous expansion of suppliers' rating coverage should lead to enhanced Scope 3 carbon accountability for a customer firm as it can compare and benchmark suppliers' performance. Following Cheng et al. (2014) and Yahia et al. (2023), we treat the initiation of environmental rating (*EnvScore*) coverage of suppliers as exogenous. Accordingly, we examine whether the initiation of suppliers' environmental rating coverage in Refinitiv affects the change in Scope 3 carbon accountability of customer firms. We construct a sample where we continue to retain observations of suppliers that are not covered by the Refinitiv database. We create a variable (*Rating Availability*) identifying the number of suppliers with an available environmental rating (*EnvScore*) for each customer-year observation. If neither of the top five suppliers of a customer has an available environmental rating, then *Rating Availability* takes a value of zero. We analyze the effect of rating availability on Scope 3 carbon accountability by regressing the Scope 3 carbon outcome on *Rating Availability* and the standard set of control variables in our baseline analyses.

We present the results in the Online Appendix, Table OA.14. The coefficient of *Rating Availability* is significantly positive for Scope 3 carbon disclosure (*t-statistic* = 3.68, $p < 0.01$) and significantly negative for Scope 3 carbon footprint (*t-statistic* = −1.99, $p < 0.05$). These results suggest that enhanced supplier environmental rating coverage allows customer firms to obtain incrementally useful information about suppliers' environmental performance. Overall, this confirms that access to suppliers' environmental information and environmental information exchange, which high-quality GSCM delivers, is crucial for supply chain carbon accountability.

4.5. Economic channels

In this section, we shed light on the two underlying channels through which the effects of GSCM quality on Scope 3 carbon accountability can be realized.

[18] One potential explanation is that the positive effect of *Supplier Env Score* on the Scope 3 carbon disclosure and performance of focal firms is due to the supplier's influence on the focal firm's carbon accountability. This explanation is mitigated as customers have greater incentives to influence supplier CSR practices rather than vice versa (Dai, Liang, et al., 2021). Moreover, the significant size difference between sizable customers and smaller suppliers in our sample implies that it is unlikely that an individual supplier exerts significant influence over its major customer's Scope 3 carbon accountability.

4.5.1. Relational trust channel

Given that suppliers contribute to a focal customer's Scope 3 carbon footprint, the customer depends on its suppliers for improvements in Scope 3 carbon accountability. GSCM practices strengthen supply chain environmental interactions and increase the level of relational trust among customer-supplier relationships (Nyaga et al., 2010; Hoejmose et al., 2012). Subsequently, a higher level of relational trust enhances suppliers' willingness to share valuable information and knowledge in relation to supply chain carbon management with corporate customers (Allameh, 2018). Moreover, strengthened relational trust motivates environmental collaboration in the aspects of joint carbon planning and cooperative problem-solving for Scope 3 carbon performance improvements (Vachon and Klassen, 2008). From a moral hazard perspective, a higher level of relational trust mitigates opportunistic behaviour by both customers and suppliers, thereby enhancing environmental collaboration (Baker et al., 2002). We posit that enhanced GSCM quality increases the level of relational trust between customers and suppliers, and through enhanced relational trust, corporate customers can better achieve their Scope 3 carbon reduction objectives. To test this, we first estimate the effect of GSCM quality on relational trust using the following model:

$$TradeCreditFinancing_{i,t+1} = \alpha_0 + \beta_1 GSCMScore_{i,t} + \sum \gamma_k Control_{i,t} + \varepsilon_{i,t} \quad (3)$$

Our proxy for relational trust between a customer and its suppliers is the extent of trade credit financing (*Trade Credit Financing*) of the customer. The offering of trade credit from suppliers to their customers depends on the level of bilateral trust (Guiso et al., 2004). Suppliers tend to bear future default risks of customers only if they sufficiently trust their customers (Xiu et al., 2023). Therefore, the amount of trade credit accessible to a customer is indicative of the level of relational trust it maintains with its suppliers (McMillan and Woodruff, 1999; Ding et al., 2023). Following prior literature (e.g., Wu et al., 2014; Kong et al., 2020), we measure trade credit financing using the amount of trade-related account payables divided by total assets. Table 5 reports the results using the one-year lead value of relational trust. The effect is positive and statistically significant (*t-statistic* = 2.93, $p < 0.01$), which provides strong support for the notion that a customer firm's high-quality GSCM enhances the level of relational trust with its suppliers.

If GSCM quality enhances relational trust for Scope 3 carbon footprint reduction, we expect the reduction effect of GSCM quality on Scope 3 carbon footprint to be stronger for customers characterized by a higher level of relational trust associated with suppliers. We directly test this effect by partitioning our sample into terciles based on the one-year lead value of relational trust (*Trade Credit Financing*) and estimating the effect of GSCM quality on Scope 3 carbon footprint (*Δ Scope3*). A customer is considered to possess low relational trust with its suppliers if it lies in the bottom tercile. Otherwise, it is considered to possess high relational trust. As reported in Table 5, find that the effect of higher GSCM quality in reducing Scope 3 carbon footprint is only significant for customer firms with higher relational trust (*t-statistic* = −2.00, $p < 0.05$). The difference in the coefficients of GSCM quality between the subsamples is statistically significant at the 5% level (*p-value* = 0.01). Overall, the combined evidence suggests that the effect of GSCM quality in reducing Scope 3 carbon footprint is realized through strengthened relational trust among customer-supplier relationships.

Table 5

Real effects of GSCM on Scope 3 carbon footprint – the channel of relational trust.

	Relational Trust	Low Relational Trust	High Relational Trust
	(1)	(2)	(3)
	Trade Credit Financing$_{t+1}$	*Δ Scope3*	*Δ Scope3*
GSCM Score	0.001***	−0.007	−0.007**
	(2.929)	(−1.468)	(−2.000)
Stock Returns	−0.005	−0.001	−0.000
	(−0.553)	(−0.181)	(−0.144)
Age	0.002***	−0.007	−0.014
	(3.325)	(−0.202)	(−0.762)
Size	0.001	−0.113	−0.157
	(0.543)	(−0.579)	(−1.546)
ROA	0.040	−0.582	3.136**
	(1.416)	(−0.313)	(2.068)
MTB	−0.012***	−0.066	0.217**
	(−7.135)	(−0.879)	(2.313)
Leverage	0.000	0.026	0.028*
	(0.033)	(0.671)	(1.799)
R&D Intensity	−0.003*	0.583	−0.110
	(−1.659)	(1.559)	(−1.087)
Staff Intensity	0.001**	−0.034	0.002
	(2.128)	(−1.180)	(0.091)
Cash Constraints	−0.064**	−0.587	−6.040*
	(−1.977)	(−0.235)	(−1.719)
Env Team	−0.019**	0.403	0.272*
	(−2.332)	(1.339)	(1.673)
Emission Policy	−0.000	−0.004	0.004*
	(−0.297)	(−0.946)	(1.861)
Board Indep	0.083***	−1.208	0.569
	(3.309)	(−1.243)	(0.876)
CSR Report	0.008	0.675	0.347
	(0.820)	(1.559)	(1.611)
ISO or EMS	0.005	0.521	−0.031
	(0.795)	(0.918)	(−0.130)
Constant	−0.050	3.280	3.350
	(−0.938)	(0.692)	(1.361)
F-test: β_1 - β_2 (p-value)		0.013	
Customer Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	1266	277	707
Adjusted R^2	0.177	0.093	0.056

Notes: This table presents the results of estimating the real effects of GSCM on Scope 3 carbon footprint through the channel of relational trust associated with suppliers. Column (1) estimates the effect of GSCM on relational trust, where the dependent variable, *Trade Credit Financing$_{t+1}$*, is the one-year lead value of total trade accounts payable scaled by total assets. Columns (2) and (3) estimate the effect of GSCM on Scope 3 carbon footprint separately for firms below and above the 1st tercile of *Trade Credit Financing$_{t+1}$* (Low *Trade Credit Financing* versus High *Trade Credit Financing*). As in our main analysis, *Δ Scope3* is the total Scope 3 carbon emissions in year $t + 2$ less the total in year $t + 1$, deflated by the total in year $t + 1$. Details on variable definitions are in Appendix A. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Robust t-statistics are reported in parentheses.

4.5.2. Supplier environmental innovation capability channel

Under GSCM, customer firms engage suppliers in training and support activities for the achievement of environmental objectives (Norheim-Hansen, 2023). These activities enhance the technical skills of supplier personnel, bring together suppliers and industry experts, educate suppliers on the importance of green practices, and equip suppliers with market intelligence on customer requirements (Krause et al., 2007). Specifically, reverse logistics allows corporate customers to obtain insights into emerging consumer environmental demand and communicate this information to their suppliers (Wu, 2008). Moreover, strengthened supply chain environmental relations enhance environmental knowledge exchange and foster the accumulation of intellectual capital. This reservoir of knowledge, coupled with a familiarity with market dynamics, fosters an environment conducive to the development of suppliers' environmental innovation capability (Wu, 2017).

Enhanced supplier environmental innovation capability promotes the development and implementation of processes to reduce focal firms' Scope 3 carbon footprint. Suppliers can leverage their innovative capabilities to improve environmental efficiency and reduce the carbon footprint of sold offerings to the focal firm (Cheng., 2020). Focal firms

Table 6
Real effects of GSCM on Scope 3 carbon footprint – the channel of supplier environmental innovation capability.

	Supplier Environmental Innovation Capability	Low Supplier Environmental Innovation Capability	High Supplier Environmental Innovation Capability
	(1)	(2)	(3)
	Supplier Env Innovation $_{t+1}$	*Δ Scope3*	*Δ Scope3*
GSCM Score	0.407***	0.000	−0.013***
	(15.715)	(0.062)	(−2.676)
Stock Returns	0.012	−0.002	−0.000
	(0.453)	(−0.377)	(−0.007)
Age	0.125	−0.067**	0.020
	(0.920)	(−2.107)	(0.694)
Size	−0.463	−0.037	−0.238*
	(−0.795)	(−0.470)	(−1.777)
ROA	4.764	5.144*	1.237
	(0.876)	(1.810)	(0.887)
MTB	0.086	0.078	0.062
	(0.260)	(0.817)	(0.858)
Leverage	0.253**	0.029	0.032*
	(2.170)	(1.342)	(1.713)
R&D Intensity	0.437	0.312	0.285*
	(1.063)	(0.905)	(1.911)
Staff Intensity	−0.068*	−0.013	−0.069**
	(−1.800)	(−0.513)	(−1.966)
Cash Constraints	−9.648	−6.675	−2.726
	(−1.458)	(−1.585)	(−1.459)
Env Team	−1.554	0.378	0.297
	(−1.064)	(1.645)	(1.572)
Emission Policy	0.032	0.001	0.005**
	(1.345)	(0.295)	(1.965)
Board Indep	−5.918	−0.044	−0.294
	(−1.183)	(−0.043)	(−0.411)
CSR Report	0.469	0.307	0.351
	(0.238)	(1.115)	(1.479)
ISO or EMS	3.028**	0.065	0.079
	(2.100)	(0.138)	(0.326)
Constant	10.344	1.906	5.397*
	(0.820)	(0.844)	(1.650)
F-test: β_1 - β_2 (p-value)		0.095	
Customer Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	1243	383	601
Adjusted R^2	0.325	0.107	0.011

Notes: This table presents the results of estimating the real effects of GSCM on Scope 3 carbon footprint through the channel of suppliers' environmental innovation capability. Column (1) estimates the effect of GSCM on supplier environmental innovation capability, where the dependent variable, *Supplier Env Innovation*$_{t+1}$, is the one-year lead average of the top five supplier's environmental innovation scores. Columns (2) and (3) estimate the effect of GSCM on Scope 3 carbon footprint separately for firms below and above the 1st tercile of *Supplier Env Innovation*$_{t+1}$ (Low *Supplier Env Innovation* versus High *Supplier Env Innovation*). As in our main analysis, *Δ Scope3* is the total Scope 3 carbon emissions in year $t+2$ less the total in year $t+1$, deflated by the total in year $t+1$. Details on variable definitions are in Appendix A. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Robust t-statistics are reported in parentheses.

can also leverage suppliers' capabilities to improve their own environmental efficiencies and reduce their downstream Scope 3 emissions. Suppliers' innovative capabilities further support the monitoring and reporting of environmental performance metrics. As a result, enhanced carbon transparency facilitates informed carbon management processes (Vaccaro and Echeverri, 2010; Feng et al., 2023). Accordingly, we posit that enhanced GSCM quality increases suppliers' environmental innovation capability, and through this channel, focal firms reduce their Scope 3 carbon footprint. To test this, we first estimate the effect of GSCM quality on suppliers' environmental innovation capability using the following model:

$$SupplierEnvInnovation_{i,t+1} = \alpha_0 + \beta_1 GSCMScore_{i,t} + \sum \gamma_k Control_{i,t} + \varepsilon_{i,t} \quad (4)$$

Our proxy for suppliers' joint environmental innovation capability of a customer firm (*Supplier Env Innovation*) is based on the top five suppliers' average environmental innovation pillar score in Refinitiv, which reflects their joint capacity to develop environmental technologies, processes, and eco-designed products (Refinitiv, 2023b). Table 6 shows the results using the one-year lead value of suppliers' environmental innovation capability. The effect is positive and statistically significant (*t-statistic* = 15.72, $p < 0.01$), which suggests that knowledge exchange with suppliers under high-quality GSCM enhances their environmental innovation capability.

If GSCM quality enhances suppliers' environmental innovation capability for Scope 3 carbon footprint reduction, we expect that the effect of GSCM quality on Scope 3 carbon footprint to be stronger for customer firms with enhanced suppliers' environmental innovation capability. We partition our sample into terciles based on the one-year lead value of suppliers' joint environmental innovation capability (*Supplier Env Innovation*) and estimate the effect of GSCM quality on Scope 3 carbon footprint (*Δ Scope3*). We consider a customer firm's suppliers to have, on average, low environmental innovation capability if the value of the measure lies in the bottom tercile. Otherwise, the suppliers are considered to possess high environmental innovation capability. As reported in Table 6, we find that the effect of higher GSCM quality in reducing Scope 3 carbon footprint is only significant for customer firms with higher supplier environmental innovation capability (*t-statistic* = −2.68, $p < 0.01$). The difference in the coefficients of GSCM quality between the subsamples is statistically significant at the 10% level (*p-value* = 0.09). Overall, the combined evidence suggests that the effect of GSCM quality on Scope 3 carbon reduction objectives is realized through the enhancement of suppliers' environmental innovation capability.

4.6. *Additional analysis*

4.6.1. *Relationship durability*

A supplier must envision clear incentives to invest in relationship-specific resources to comply with a corporate customer's GSCM protocols (Bai and Satir, 2020). As a customer can renegotiate contract terms or switch to an alternative supplier to the detriment of the original supplier, GSCM practices can lead to hold-up problems and hinder Scope 3 carbon reduction (Lumineau et al., 2022). We expect a supplier's cooperation with a customer's Scope 3 carbon reduction initiatives to increase the durability of their relationship. Durable long-term relationships are characterized by an existing larger accumulation of relationship-specific assets (Joskow, 1987) and higher mutual dependence (Casciaro and Piskorski, 2005), which act as incentives for both the supplier and customer to maintain the relationship and strategically align their environmental interests. Furthermore, durable relationships entail a greater cost of switching to a new supplier or customer, involving the resources necessary to establish new processes and adapt to the dynamics of a different business partner (Burnham et al., 2003).

To test this, we partition our sample into observations of customers with low and high average supplier relation durability based on the sample median value of the average durability of the customer's relationships with suppliers (*Ave Rel Durability*). Specifically, it is measured as the average number of years of a customer's relationship with each of its top five suppliers. Table 7 reports that the effect of GSCM quality in reducing Scope 3 carbon footprint is only significant whereby the customer possesses high relationship durability with its suppliers (*t-statistic* = −3.014, $p < 0.01$). The difference in the coefficients of GSCM

Table 7
GSCM and Scope 3 carbon footprint – the conditioning effect of relationship durability.

	Δ Scope3	
	(1) *Ave Rel Durability* Low	(2) *Ave Rel Durability* High
GSCM Score	−0.002	−0.015***
	(−0.358)	(−3.014)
Stock Returns	−0.005	0.002
	(−1.013)	(0.433)
Age	−0.043*	−0.003
	(−1.730)	(−0.120)
Size	−0.128	−0.220
	(−1.617)	(−1.592)
ROA	4.108*	2.608**
	(1.850)	(1.985)
MTB	0.156**	−0.135*
	(2.323)	(−1.726)
Leverage	0.013	0.023
	(0.661)	(1.189)
R&D Intensity	0.332	0.125
	(1.050)	(1.392)
Staff Intensity	−0.026	−0.083**
	(−0.877)	(−2.340)
Cash Constraints	−6.725	−0.869
	(−1.647)	(−0.611)
Env Team	0.336	0.372*
	(1.392)	(1.857)
Emission Policy	−0.001	0.008**
	(−0.282)	(2.486)
Board Indep	−0.864	0.765
	(−0.945)	(1.056)
CSR Report	0.321	0.293
	(1.233)	(1.227)
ISO or EMS	0.380	−0.127
	(0.870)	(−0.492)
Constant	4.471*	4.336
	(1.827)	(1.344)
F-test: β_1 - β_2 (p-value)	0.036	
Customer Industry FE	Yes	Yes
Year FE	Yes	Yes
Observations	411	573
R^2	0.158	0.020

Notes: This table reports the conditioning effect of relationship durability on the relationship between GSCM and Scope 3 carbon footprint. We measure the average relationship durability (*Ave Rel Durability*) of a customer firm with its suppliers using the mean number of years across the relationships with its top five (n) suppliers. We partition our sample based on the sample median value of *Ave Rel Durability*. Across the subsamples, we retain observations where less than five suppliers are identified ($n = 1$ for 218 obs., $n = 2$ for 177 obs., $n = 3$ for 103 obs., $n = 4$ for 77 obs., $n = 5$ for 409 obs.). Details on variable definitions are in Appendix A. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Robust t-statistics are reported in parentheses.

quality between the subsamples is statistically significant at the 5% level (*p-value* = 0.04). This result suggests that stronger relationship durability facilitates investments in relationship-specific investments for supply chain carbon footprint reduction.

5. Conclusion and implications

Emerging corporate sustainability disclosure mandates are placing a heightened emphasis on supply chain carbon accountability. As firms possess limited knowledge of their Scope 3 carbon footprint, environmental interactions with supply chain participants under GSCM promote the carbon information exchange necessary to achieve Scope 3 carbon objectives. We provide empirical evidence that enhanced GSCM quality, defined as the extent to which a focal firm integrates environmental objectives into the management of its supply chain relationship, motivates Scope 3 carbon disclosures and reduces Scope 3 carbon footprint. This suggests that GSCM practices form a distinct and important component of corporate environmental governance. The desirable effects of GSCM quality are realized through improvements in relational trust with suppliers and in suppliers' environmental innovation capabilities. These channels underscore the importance of information exchange and collaboration as the foundation of green supply chains. We also find that the effects of GSCM quality are discernible among durable customer-supplier relationships, suggesting that drivers of longstanding customer-supplier ties are important for supply chain carbon accountability.

Our study has important implications for managers, particularly firms that will be eligible under emerging disclosure mandates to disclose their Scope 3 emissions and supply chain activities. First, we document that GSCM quality is crucial for firms seeking to achieve regulatory compliance. As existing Scope 3 carbon disclosures are highly inconsistent and sparse, the enforcement of GSCM quality improvements is an important stepping stone towards compliance with supply chain disclosure frameworks. Second, enhancements in GSCM quality lead to improved relational trust and suppliers' environmental capabilities, with implications on Scope 3 carbon footprint and other environmental objectives. Thus, GSCM can be utilized by focal firms seeking to address the emerging environmental demands of environmental NGOs, the wider public, and its consumer markets.

From a policy standpoint, enhanced visibility driven by GSCM practices coupled with mandatory disclosures promotes regulatory efficiency. Policymakers and regulators can benefit from GSCM-driven supply chain carbon transparency and accountability to achieve international and domestic environmental goals. First, the imposition of GSCM requirements top-down from large, listed firms enables greening of the supply chain, wherein large firms will influence the environmental performance of their smaller suppliers. This permeation of environmental behaviour will significantly contribute to the sustainable development of the global economy.

Second, GSCM quality plays an important role in the achievement of several Sustainable Development Goals (SDGs) to promote sustainable economic growth in developing countries (UN, 2023a). The inadequate transparency on supply chain carbon footprint incentivizes carbon shifting, whereby artificial improvements in firm-specific emissions are obtained by outsourcing carbon-intensive production (Dai et al., 2021a). Berry et al. (2021) document the existence of a pollution haven effect whereby a large fraction of US manufacturing imports are sourced from developing countries with less stringent environmental standards. By documenting that high-quality GSCM reduces Scope 3 carbon footprint, we highlight the importance of supply chain carbon accountability in mitigating carbon shifting. Therefore, GSCM quality facilitates the achievement of inclusive and sustainable economic growth in the interests of developing countries.

Overall, it is important for US policymakers to comprehend the impact of US firms on global supply chain networks, considering that the US possesses the largest stock exchanges in the world by market capitalization. In the US where Scope 3 emission reporting has been excluded from the climate disclosure rule due to data limitations, GSCM quality emerges as a critical success factor for the potential transition into mandatory Scope 3 reporting. Similarly, policymakers of other nations can build the foundations for Scope 3 carbon reporting through the mandatory enforcement of GSCM practices among large firms. Therefore, GSCM quality serves as an important stepping stone towards global Scope 3 carbon accountability.

For standard-setters, the inclusion of specific metrics related to GSCM practices within environmental reporting frameworks can be beneficial to stakeholders in assessing firms' supply chain environmental accountability. The important role of GSCM in environmental protection highlights that such an inclusion will provide environmental benefits for a nation. Future standards will benefit from the groundwork of the EU's 2022 Directive for Corporate Sustainability Due Diligence in global supply chains (EC, 2022). Notably, the development of GSCM practices across different industries will support standard-setters in revising and updating reporting frameworks to be more effective in communicating corporate environmental behaviour to stakeholders.

Our findings also have implications for investors, shareholders, consumers, and suppliers. We highlight that it is important to consider GSCM practices collectively when evaluating a firm's supply chain carbon accountability. Specifically, a cohesive suite of GSCM strategies, forming GSCM quality, is important in managing suppliers' environmental performance, as individual operational GSCM practices in isolation yield limited benefits (Villena and Gioia, 2020). It is also important to assess the durability of a focal firm's supplier relationships in assessing its supply chain carbon accountability. Moreover, a higher quality of GSCM benefits end consumers in the form of enhanced access to detailed carbon footprint information for informed consumption and purchase. This also allows firms to gain economic benefits in return for their emission abatement efforts. From the suppliers' standpoint, leveraging the green supply chain management practices of a corporate customer can yield positive externalities. These include the development of their own environmental innovation capabilities to benefit their stakeholder relationships beyond those associated with the corporate customer.

Our study has several implications for future research. While our results imply that the GSCM practices of US firms will have carry-on effects on their suppliers, our sample is restricted to US suppliers of US focal customer firms. This is an inherent limitation due to the reliance on US supplier-disclosed customer relationships. Future research can extend this study to incorporate global suppliers and customer firms, which will facilitate investigations into spillover effects across countries considering the influence of different institutional settings, including national regulations and culture. The novel measures of GSCM quality also reshape future research into the influence of GSCM practices on organizational and interorganizational outcomes.

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CRediT authorship contribution statement

Millie Liew: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **June Cao:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

None.

Data availability

Data used in this study are available from the sources identified in the text.

Appendix A. Variable construction

Variable	Category	Operationalization	Data source
Scope3 Disclosure	Dependent	An indicator variable equals one if a firm reports Scope 3 emissions in addition to Scope 1 and Scope 2 emissions. This variable equals zero if the firm only reports Scope 1 and Scope 2 emissions.	Refinitiv
Δ Scope3	Dependent	Year-on-year change in Scope 3 carbon footprint. The amount of upstream and downstream (Scope 3) carbon emissions reported is used. We take the total Scope 3 carbon emissions in year $t+2$ less the total in year $t+1$, then deflate this difference by the total in year $t+1$.	Refinitiv
Δ Scope3/Sales	Dependent	Year-on-year change in Scope 3 carbon footprint scaled by total sales. The amount of upstream and downstream (Scope 3) carbon emissions reported is scaled by total sales (in $10,000 s). We take the scaled total Scope 3 carbon emissions in year $t+2$ less the scaled total in year $t+1$, then deflate this difference by the scaled total in year $t+1$.	Refinitiv, Compustat
EnvScore	Independent	Environmental pillar score of a firm.	Refinitiv
Procurement	Independent	The natural logarithm of the total procurement of a customer firm from a supplier.	Refinitiv
GSCM Score	Independent	The measure of a focal firm's green supply chain management quality is calculated as the sum of the procurement-weighted *EnvScore* of each of the top five suppliers. Specifically, it is constructed as: $GSCMScore_{i,t} = \sum_{j=1}^{n}\left(EnvScore \text{ of Supplier } j \, x \, \frac{\text{Firm } i\text{'s } Procurement \text{ from Supplier } j \text{ in year } t}{\text{Firm } i\text{'s total } Procurement \text{ from top } n \text{ suppliers in year } t}\right)$ The procurement ratio for each supplier *j* is calculated by dividing firm *i*'s procurement from supplier *j* by firm *i*'s total procurement from its top *n* suppliers. The value of *n* ranges from one to five. *EnvScore* is multiplied by the procurement ratio to obtain the procurement-weighted *EnvScore*. *GSCM Score* is then calculated as the sum of weighted *EnvScore*.	Compustat Segments
GSCM Scale	Independent	The measure of a focal firm's green supply chain management quality is based on eight indicator variables reported in Refinitiv or calculated based on Refinitiv scores, as detailed in Table OA.2 in the Online Appendix.	Refinitiv
Age	Control	The number of years since the firm first appeared in the Compustat database.	Compustat
Size	Control	The natural logarithm of one plus total assets value.	Compustat
ROA	Control	Return-on-assets, defined as the ratio of net income to total assets.	Compustat
MTB	Control	The market to book value is defined as the total market value of equity and liabilities scaled by the book value of the total assets.	Compustat
Leverage	Control	Total leverage is defined as long-term debt (Compustat item: DLTT) plus debt in current liabilities (Compustat item: DLC) divided by the book value of the common equity.	Compustat
R&D Intensity	Control	Research and development intensity is measured using research and development expenses deflated by the value of total assets. To account for missing R&D, we follow Koh and Reeb (2015) and replace missing R&D with the two-digit industry average.	Compustat
Staff Intensity	Control	Staff intensity is measured using the number of employees divided by total sales in millions.	Compustat
Cash Constraints	Control	The level of cash constraints measured using net cash flows from operating activities scaled by total assets.	Compustat
Env Team	Control	An indicator variable equals one if the firm has an environmental management team. An environmental management team is defined as any team comprising one or more operational (i.e., non-director) employees that performs the functions dedicated to environmental issues, regardless of its naming.	Refinitiv

(*continued on next page*)

(*continued*)

Variable	Category	Operationalization	Data source
Emission Policy	Control	An indicator variable equals one if the firm has a policy to improve emissions reduction. An identified policy (1) details the mechanisms or programs in place to reduce operational emissions and (2) provides a set of formal, documented processes for controlling emissions and driving continuous improvement.	Refinitiv
Board Indep	Control	Percentage of independent board members of the firm.	Refinitiv
CSR Report	Control	An indicator variable equals one if the firm publishes a CSR or sustainability report separately or within its annual financial report.	Refinitiv
ISO or EMS	Control	An indicator variable is equal to one if the firm claims to have an ISO 14000 or EMS certification and equal to 2 if both. This variable equals zero if the firm merely states adherence to ISO 14000 or EMS without certification.	Refinitiv
Stock Returns	Control	Annual stock return is defined as the closing share price minus the opening share price in year *t*.	Compustat
Trade Credit Financing	Mechanism	Total trade accounts payable scaled by total assets.	Compustat
Supplier Env Innovation	Mechanism	The average of the top five suppliers' environmental innovation score which reflects their joint capacity to develop environmental technologies, processes, and eco-designed products.	Refinitiv
Ave Rel Durability	Moderator	The average durability (*Rel Durability*) of a customer firm's relationships with its top five suppliers.	Compustat Segments
GovScore	Robustness	The governance pillar score of the firm measures the extent to which its systems and processes ensure its board and executives act in the best interests of its long-term shareholders.	Refinitiv
CSR Committee	Robustness	An indicator variable equals one if the firm has a CSR committee at the board or senior management level.	Refinitiv
CSR Strategy	Robustness	CSR strategy score reflects the firm's practices to communicate that it integrates the economic, social, and environmental dimensions into its day-to-day decision-making processes.	Refinitiv
Env Train	Robustness	An indicator variable equals one if the firm trains its employees on environmental issues, whether internally or through external trainers.	Refinitiv
Scope1/Sales	Robustness	The measure of Scope 1 carbon emission intensity is defined as total Scope 1 carbon emissions deflated by total sales (in $10,000 s).	Refinitiv, Compustat
Scope2/Sales	Robustness	The measure of Scope 2 carbon emission intensity is defined as total Scope 2 carbon emissions deflated by total sales (in $10,000 s).	Refinitiv, Compustat
Top 3 GSCM Score	Robustness	A modification of the *GSCM Score* based on the top three suppliers ranked by the firm's procurement from each disclosed supplier in Compustat Segments. Specifically, it is calculated as the sum of the procurement-weighted *EnvScore* of each of the top three suppliers.	Compustat Segments, Refinitiv
Top 1 GSCM Score	Robustness	A modification of the *GSCM Score* based on the top one supplier ranked by the firm's procurement from each disclosed supplier in Compustat Segments. Specifically, we take the *EnvScore* of the top one supplier.	Compustat Segments, Refinitiv
Procurement	Robustness	Total procurement by the firm from its supplier.	Compustat Segments
Rel Durability	Robustness	The durability of the customer-supplier relationship between the firm and its supplier is defined as the number of years since the relationship first appeared in the database.	Compustat Segments
Cost of Sales	Robustness	Total cost of sales of a firm.	Compustat
Rating Availability	Robustness	The number of identified suppliers with available *EnvScore*.	Refinitiv

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2024.107840.

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