

## RESEARCH ARTICLE

WILEY

# Customer base environmental disclosure and supplier greenhouse gas emissions: A signaling theory perspective

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**Handling Editors:** Robert Klassen, Christina W.Y. Wong, and Qingyu Zhang

## Abstract

As suppliers' emissions contribute to a significant portion of the global environmental footprint, achieving supply chain wide carbon neutrality largely depends on suppliers' greenhouse gas (GHG) emissions reductions. Although suppliers' customers are increasingly signaling their commitment to tackling climate change through environmental disclosure, whether this signal contributes to supplier emissions reduction remains a question. Using signaling theory, this research proposes an emissions-reducing effect of customer base environmental disclosure on a supplier's GHG emissions level. Using a 2010–2017 panel dataset from multiple sources, we find empirical evidence supporting the upstream emissions-reducing effect of customer base environmental disclosure. Further, we identify two customer-base characteristics that affect this relationship: customer base climate innovation and competition. These findings contribute to the sustainable supply chain management literature by illustrating the effects of the customer base on supplier emissions performance. Specifically, customers could motivate a supplier's engagement in emissions reduction by collectively signaling their environmental commitment through enhanced disclosure. However, the effectiveness of this signaling effect can be contingent on the green innovation and competitive dynamics of the customer base.

## KEYWORDS

environmental disclosure, GHG emissions, signaling theory, supply chain decarbonization

## Highlights

- Customers' disclosure of environmental information (i.e., customer base environmental disclosure) motivates suppliers to reduce emissions and thus can drive supply chain decarbonization.
- Customer base climate innovation and competition alter the effect of customer base environmental disclosure on supplier emissions reduction, and the effect is stronger in less competitive or climate innovative customer bases.
- Mandatory environmental disclosure regulation on customers could be a means to reduce emissions throughout the supply chain, especially in industries where customers share fewer suppliers and invest less in climate innovations.

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## 1 | INTRODUCTION

The 2021 Intergovernmental Panel on Climate Change (IPCC) concluded that Earth has warmed approximately 1.1 degrees Celsius since the pre-industrial era and that the pace of climate change will increase if no strong measures are taken (IPCC, 2021). With the clear evidence of global warming, stakeholders have pressured manufacturers and their supply chains to substantially reduce their climate impact (Jeong & Lee, 2022). For this reason, many manufacturers have set carbon neutrality targets. For example, Procter & Gamble, a multinational consumer goods manufacturer, announced its science-based carbon neutrality target in its 2015 sustainability report, committing to reduce total Scope 1 and 2 emissions by 30% by 2020 (P&G, 2015).<sup>1</sup> However, stakeholders also need to track performance to these targets, which has led to manufacturers also becoming more transparent regarding their environmental impact and practices through increased public disclosure (hereafter referred to as environmental disclosure) to signal their value and commitment to addressing climate change (Bellamy et al., 2020; Hora & Subramanian, 2019).<sup>2</sup>

While manufacturers have improved their environmental disclosure to meet stakeholder expectations on addressing climate change, the achievement of carbon neutrality requires emissions reduction by their suppliers because “supply chain emissions are on average 11.4 times higher than operational emissions” (Carbon Disclosure Project, 2021, p. 5). However, many manufacturers have not included supply chain emissions when setting carbon neutrality targets. For example, while it has become common to disclose Scope 1 and Scope 2 emissions, only 11% of the firms pledging or committing to carbon neutrality targets disclose Scope 3 emissions, which are the indirect emissions that occur in the firms’ value chains, including both upstream and downstream activities (Corkery & Creswell, 2021). The limited attention and visibility paid to supply-chain emissions could incentivize manufacturers to improve their Scope 1 and Scope 2 emissions by outsourcing “dirty production” (Duan, Ji, et al., 2021, p. 1) to their suppliers to look better in the eyes of their stakeholders (Berry et al., 2021; Dai, Duan, et al., 2021). This may potentially create negative externalities for the achievement of carbon neutrality. For example, Levi Strauss disclosed its climate action strategy in 2017, which set an emissions-cutting target by 2025. However, Levi Strauss ended up with an increase in supply chain emissions between 2016 and 2019 (Eavis & Krauss, 2021). For this reason, supplier GHG emissions could increase as the level of environmental disclosure from a supplier’s customers (e.g., the manufacturers) increases.

However, an increase in environmental disclosure from a supplier’s customers could also lead to a reduction in supplier GHG emissions. Specifically, manufacturers’ environmental disclosure may signal their climate change commitment to their suppliers (Duan, Hofer, et al., 2021; Hahn et al., 2015), and the strength of that signal increases as manufacturers disclose more environmental information (Wu et al., 2020). A supplier may respond to this signal by reducing emissions in anticipation of its customers extending environmental policies and programs to the supplier to avoid risks and penalties from its customers, such as losing business, and to stay competitive in markets, such as being a preferred supplier or getting long-term contracts from customers (Dai, Liang, et al., 2021; Plambeck, 2012). For example, Hewlett Packard Enterprise (HPE) committed to spending 80% of its manufacturing spend by 2025 on suppliers with science-based carbon reduction targets (SBTi, 2018), leaving a small percentage of business to those who do not qualify. In sum, a supplier’s emissions could increase or decrease as a result of its customers’ environmental disclosure. To better understand this phenomenon, we investigate the relationship between a supplier’s GHG emissions performance and the level of environmental disclosure of the supplier’s customers.

To investigate this relationship, we examine the collective disclosure across all of a supplier’s direct customers, or, in other words, the customer base.<sup>3</sup> We focus on the customer base, as opposed to individual customers or firms further downstream in the supply chain (i.e., indirect customers), for two reasons. First, a supplier typically provides products and services to multiple customers, and thus the supplier’s decisions can be better explained by the aggregated behaviors and characteristics of these customers as a whole as opposed to individual customers (Johnsson & Moon, 2021; Manski, 1993), particularly in the context of environmental management (Jira & Toffel, 2013). Second, environmental disclosures by a supplier’s direct customers are more visible to the supplier, thus creating a greater influence than disclosures of indirect customers with whom the supplier does not have business relationships. For these reasons, we examine the following research question: *Is customer base environmental disclosure positively or negatively associated with a supplier’s GHG emissions?*

Environmental disclosure could serve as a signal of customers’ climate commitment, pressuring suppliers to reduce emissions. However, for such a signal to truly lead to a supplier’s emissions reduction depends on whether the signal is strong and credible, as the supplier needs to clearly receive the signal and feel pressure to respond after receiving it. Therefore, we examine two customer base characteristics that could affect this process and thus

the influence of customer base environmental disclosure on supplier emissions. The first factor is customer base climate innovation (i.e., the average level of customers' innovation in climate-related technologies) (Hege et al., 2022). Customer base climate innovation is a clear and credible signal of customers' commitment towards addressing climate change, which may strengthen and validate the signal from customer environmental disclosure. Hence, a supplier may be more likely to reduce emissions when customers are engaged in both environmental disclosure and climate innovation. In addition, the extent to which a supplier responds to customer base signals depends on the pressure felt by the supplier to react. One aspect that affects such pressure could be the presence of competing customers in a supplier's customer base. For example, many competing cellular phone manufacturers use the same material for screens on their products, Corning® Gorilla® Glass, which results in these manufacturers all sourcing from Corning (Simons, 2022), making Corning difficult to replace and increasing Corning's power in these relationships. As a result, Corning is in a stronger bargaining position and thus more able to resist pressures to respond to customer signals. Therefore, the second factor we examine is customer base competition (i.e., the extent to which customers compete with other customers in the base). These discussions bring us to the second research question: *Will customer base climate innovation and competition moderate the relationship between customer base environmental disclosure and a supplier's GHG emissions?*

We collect data from multiple sources, which include Bloomberg environmental, social, and governance (ESG), FactSet Revere, United States Patent and Trademark Office (USPTO), Compustat, and additional supplementary datasets. Our final sample contains 2434 supplier-year observations for 531 unique first-tier suppliers of manufacturing firms from 2010 to 2017. Based on a fixed-effects model estimation, our results show that customer base environmental disclosure is negatively associated with supplier GHG emissions levels. Thus, customer base environmental disclosure may serve as a strong signal to a supplier to reduce GHG emissions. We also find that customer base competition positively moderates the main effect, suggesting that the effectiveness of disclosure signal may depend on supplier power, as a powerful supplier is less likely to succumb to signals and pressure from the customer base. Contrary to our predictions, our result shows that the main relationship may be attenuated when a customer base has high climate innovation performance. We explore this counterintuitive result in our extended analyses.

Our study contributes to the sustainable supply chain management literature. The literature on low-carbon

supply chains primarily focuses on suppliers' emissions disclosure rather than suppliers' emissions reduction (e.g., Jira & Toffel, 2013; Villena & Dhanorkar, 2020), whereas this study shows that customer base environmental disclosure could contribute to suppliers' emissions reduction. We also identify two moderating factors, customer base climate innovation and competition, that provide boundary conditions for the signaling effect of customer base environmental disclosure in supply chains. Together, these findings present both the opportunities and the constraints for leveraging downstream environmental disclosure to motivate upstream engagement in reducing emissions for carbon neutrality. From a managerial standpoint, these findings provide managers with suggestions to affect supplier emissions in order to achieve supply chain decarbonization. From a policy standpoint, the U.S. Securities and Exchange Commission (SEC) has proposed rules on disclosing climate-related information to investors (Gensler, 2022), yet questions remain on the disclosure's scope, effectiveness, and potential negative impacts on competitiveness (Aragón-Correa et al., 2020; Seiger et al., 2022). Our findings provide empirical support for the value of collective environmental disclosures by customers in affecting supply chain emissions reduction in the pursuit of carbon neutrality.

## 2 | LITERATURE REVIEW

As a key environmental issue, emissions reduction has long been the focus of scholarly research. The related research has examined factors that drive firms' adoption of emissions reduction practices (Damert et al., 2018; Dhanorkar et al., 2018; Ehr Gott et al., 2013; Hardcopf et al., 2019; Heitz et al., 2021; Hofer et al., 2012) and factors that improve emissions reduction performance (Adhikary et al., 2020; Dooley et al., 2019). Our research is related to the latter stream, where studies have predominantly taken a firm-centric view to understand emissions reduction, as opposed to a supply chain view. For example, existing literature examines firms' operational leanness (Fu et al., 2019; Rothenberg et al., 2001), operational levers for compliance (Kroes et al., 2012), visibility (Delmas & Montes-Sancho, 2010), governance structure (Lin et al., 2014), and management attitudes (Pagell & Gobeli, 2009). While there is a growing interest in supply chain emissions in the recent literature (e.g., Gopalakrishnan et al., 2021; Plambeck, 2012), research on the antecedents to suppliers' emissions performance is scarce, which is surprising given that supplier emissions are critical in achieving carbon neutrality (Gopalakrishnan et al., 2021). Our study contributes to

this literature stream by examining the effects of customer base environmental disclosure as a critical driver for supply chain decarbonization.

Our research also relates to the environmental disclosure literature. An increasing number of firms voluntarily engage in environmental disclosure to respond to pressures from members of their supply chains (Jira & Toffel, 2013; Villena & Dhanorkar, 2020), peers (Ott et al., 2017; Villena & Dhanorkar, 2020), shareholders (Reid & Toffel, 2009), and regulators (Jira & Toffel, 2013; Reid & Toffel, 2009). Firms' disclosures can differ in channels (Clarkson et al., 2008), scope (Bellamy et al., 2020), and quality (Marquis et al., 2016). Factors such as environmental performance (Blanco, 2021; Clarkson et al., 2008; Fabrizio & Kim, 2019), stakeholders' pressure (Marquis et al., 2016; Villena & Dhanorkar, 2020), and organizational innovations (Bellamy et al., 2020) can also affect the extent to which firms disclose their environmental performance. The consequences of environmental disclosure have also been investigated, with one stream focusing on firms' economic and financial outcomes (Buell & Kalkanci, 2021; Duan, Hofer, et al., 2021; Jacobs, 2014; Jacobs et al., 2010) and another stream focusing on how one firm's environmental disclosure affects its environmental behaviors and performance and those of its stakeholders (Hora & Subramanian, 2019; Yang et al., 2021; Yin & Wang, 2018). Our research is closely related to the latter stream. For example, Toffel and Short (2011) investigate the impact of a firm's voluntary disclosure of environmental violations on the regulatory scrutiny faced by the firm and the firm's environmental performance. Notably, a firm's environmental disclosure has been found to increase supply chain emissions because "firms can simply move economic activity, and emissions, outside the scope of disclosure" (Yang et al., 2021, p. 25). Outsourcing emissions to the supply chain, which is often referred to as carbon leakage, may occur when firms want to maintain a good reputation and social capital without making substantial efforts (Dai, Duan, et al., 2021) to address pressures from local (Li & Zhou, 2017) and national institutions (Berry et al., 2021). Our study contributes to the literature by examining the effect of customer base environmental disclosure on suppliers' emissions.

### 3 | HYPOTHESES DEVELOPMENT

We draw on signaling theory to develop our hypotheses. Signaling theory has been used in the operations management literature to analyze how signalers, the customer base in this study, impact the decisions of receivers, the suppliers in this study, through a signaling process (Connelly et al., 2011). According to signaling theory,

there is a signaler and a receiver, and there is information asymmetry between the two parties. Signalers are insiders who have complete information, and receivers are outsiders who lack information but would like to receive the information to make decisions (Yan et al., 2020). Once a signal is sent by a signaler and observed by the receiver, the receiver interprets the signal and makes decisions. Essentially, the signaling process is used to reduce the information asymmetry between the two parties to help receivers make more informed decisions regarding performance improvement (Connelly et al., 2011).

Information asymmetry between customers and a supplier is a common occurrence (Ciliberti et al., 2011) and is particularly relevant to sustainability issues, such as carbon emissions reduction, as the supplier often does not have full information about what is expected by its customers in terms of emissions performance (Wilhelm et al., 2016). In addition, as a supplier is located more upstream in supply chains, the supplier is often farther away from public scrutiny and market pressure to reduce carbon emissions (Li & Zhou, 2017). Therefore, the actions of a supplier's customers play a significant role in the supplier's engagement in emissions reduction. Prior to undertaking costly and uncertain environmental initiatives, the supplier needs to sense strong and trustworthy signals regarding environmental commitment from its customers to understand and evaluate the potential outcomes of not responding (Jira & Toffel, 2013). Customer environmental disclosure can serve as a signal of environmental commitment to suppliers.

The strength of an environmental disclosure signal depends on signal clarity and credibility (Heil & Robertson, 1991). Receivers should easily observe a clear signal (Connelly et al., 2011) that "is unambiguous and has a known cause" (Heil & Robertson, 1991, p. 409). Thus, a signal with high clarity should carry few alternative meanings (Heil & Robertson, 1991). Likewise, the credibility of the signaler's commitment is an essential prerequisite for a signal to work (Heil & Robertson, 1991; Kotha et al., 2018; Steigenberger & Wilhelm, 2018). A credible signal is costly (Connelly et al., 2011; Duan, Hofer, et al., 2021), so senders without such commitment do not want to mimic it (Flammer, 2021; Spence, 1974). For example, oil-and-gas producers can credibly signal their climate commitment by investing in reducing methane leakage in their operations because many producers resist making such costly investments (Ferek, 2022). A signal's credibility also relies on verifiability (Mavlanova et al., 2012). For example, third-party assurance enhances the credibility of CSR reports in signaling commitment (Bagnoli & Watts, 2017).

In the following sections, we discuss how an increase in environmental disclosures from the customer base can



strengthen the clarity and credibility in signaling customers' environmental management commitment and, as a result, may induce a supplier to reduce emissions. However, the signaling effect can be influenced by customer base characteristics. In particular, customer base climate innovation and competition may affect the strength of the commitment signal and thus the supplier's responses to the signal. Therefore, we also examine the moderating effects of these factors.

### 3.1 | Customer base environmental disclosure

Environmental disclosure can yield commercial and financial benefits (Buell & Kalkanci, 2021; Duan, Hofer, et al., 2021; Jacobs, 2014; Jacobs et al., 2010; Martin & Moser, 2016), but can also raise stakeholders' expectations regarding environmental performance improvement (Gopalakrishnan et al., 2021), putting pressure on firms to reduce their GHG emissions. This could result in an increase in suppliers' GHG emissions, as some customers may try to reduce their emissions at the expense of their suppliers (i.e., shifting dirty activities to the supply chains), often referred to as carbon outsourcing or leakage (Böhringer et al., 2014; Mi et al., 2017). Thus, an increase in customer base environmental disclosure could lead to an increase in a supplier's GHG emissions.

However, we posit that customers' environmental disclosure leads to a decrease in a supplier's GHG emissions due to a signaling effect. Addressing climate risks and emissions reduction has become a common goal for supply chain partners (Villena & Dhanorkar, 2020), and the pressure for emissions reduction should only increase in the future. While environmental disclosure could lead some opportunistic customers to engage in carbon outsourcing, for the majority of customers, environmental disclosure is more likely to be a signal of those firms' environmental commitment (Duan, Hofer, et al., 2021; Hahn et al., 2015), allowing them to differentiate themselves from the firms that are not committed to environmental improvement (Wu et al., 2020). Therefore, a customer's environmental disclosure should serve as a strong signal of downstream climate commitment to a supplier, especially when multiple customers are disclosing high levels of environmental information.

The strength of this signaling effect increases with the extent to which a customer discloses its environmental performance. First, the more a customer discloses its environmental performance, the easier it is for the customer's major stakeholders to be aware of the customer's environmental commitment (e.g., the disclosure is more likely to be reported in the media). Stakeholders also have incentives to access comprehensive disclosed information

because they can make more informed decisions with less information asymmetry (Özer et al., 2018). Second, as more environmental information is disclosed, a customer sends a clearer signal to the market about its environmental commitment, distinguishing the firm from those with selective or no disclosure (Marquis et al., 2016). Third, the costs associated with environmental disclosure make it a credible commitment signal. Environmental disclosure is costly due to not only the resources and efforts needed to collect data but also the uncertainty of how stakeholders will use the information (Jira & Toffel, 2013). For example, stakeholders may require expensive environmental improvement actions after collecting environmental information (Jira & Toffel, 2013). Because of these costs, a firm without environmental commitment might not want to mimic leading firms with high levels of environmental information disclosure (Wu et al., 2020).

As more of a supplier's customers signal their climate commitment through environmental disclosure, the supplier is more motivated to invest in costly environmental initiatives to reduce GHG emissions (Damert et al., 2018; Plambeck, 2012; Ramanathan et al., 2014). Environmental disclosure has been shown to be associated with an increase in the adoption and diffusion of environmental management practices (Blanco et al., 2016; Blanco et al., 2017). Therefore, environmentally responsible customers "can infuse similar socially responsible business behavior in suppliers" (Dai, Liang, et al., 2021, p. 598) by selecting suppliers that have similar environmental practices or pushing suppliers to adopt similar practices (Dai, Liang, et al., 2021). Therefore, a supplier would anticipate its customers disseminating environmental practices throughout their supply chains (Angell & Klassen, 1999; Corbett, 2006; Corbett & Kirsch, 2001; Wilhelm & Villena, 2021). Additionally, the supplier may also anticipate that if it does nothing to manage its environmental performance, it will face future risks and costs, such as a reduced or loss of business (Dai, Liang, et al., 2021) or collective sanctions (Thompson et al., 2015) from multiple customers who value environmental performance. Therefore, when there is an increase in environmental disclosure in the customer base, the supplier may commit their efforts to reduce GHG emissions. Formally, we hypothesize:

**H1.** Customer base environmental disclosure is negatively associated with supplier GHG emissions.

### 3.2 | Customer base climate innovation

Achieving the goal of carbon neutrality will require substantial investment in climate-related innovation

(Van Wassenhove, 2019; Wang, Harindintwali, et al., 2021). Climate-related innovation can improve energy efficiency (Sun et al., 2019), result in green products and packages (Dangelico, 2016), ease renewable energy generation and distribution (Johnstone et al., 2010), and capture and store emissions (Beck, 2020). For example, Sony developed new LED displays for its TV products, which can reduce consumer energy usage by 20%, and new recycled plastic, which can reduce emissions by 80% during manufacturing (SBTi, 2020). While climate innovation is beneficial for firms to improve environmental performance, such innovation is often costly (Wang, Cho, et al., 2021). For example, Apple issued \$4.7 billion of Green Bonds to help innovate in low-carbon manufacturing and recycling processes (Apple, 2022). These costly investments in climate innovation, which are observable through, for example, green patents, may send a credible signal of customer commitment to addressing climate risks (Aghion et al., 2020; Flammer, 2021).

Because both climate innovation and environmental disclosure can signal customer climate commitment, the combination of the two may be stronger than either alone (Steigenberger & Wilhelm, 2018). When climate innovation in the customer base is high, a supplier is more likely to interpret the disclosure signal as customers' sincerity towards reducing emissions due to the costly nature of climate innovations, strengthening the clarity of the disclosure signal. In addition, climate innovation provides an opportunity for a signal consistency check—the supplier can “cross-validate meanings inferred from signals that are of direct concern” (Heil & Robertson, 1991, p. 410). The consistency between the two signals strengthens the credibility of the climate commitment interpretation. In sum, a customer base with high levels of climate innovation may strengthen the signaling effect of environmental disclosure, leading the supplier to take stronger actions toward emissions management (Connelly et al., 2011; Heil & Robertson, 1991). Therefore, we hypothesize:

**H2.** The negative association between customer base environmental disclosure and supplier GHG emissions is stronger when the customer base has high climate-related innovation performance.

### 3.3 | Customer base competition

Customer base competition refers to the number of competitive relationships within a supplier's customers, and the extent to which customer base competition happens has implications for explaining the customer base's influence on supplier behavior. For example, Corning Inc.

provides glass products to Apple and Samsung, both competing in consumer electronics products, and to Daimler and Volkswagen, who compete in motor vehicles. Research has examined the effects of this supply chain structure on quality management (Agrawal et al., 2016; Muthulingam & Agrawal, 2016), capacity investment (Qi et al., 2015), outsourcing contracts (Feng & Lu, 2013), and organizational learning (Dyer & Hatch, 2006). Such a supply chain structure is also relevant to our context because the responses to a signal and the subsequent decisions to address emissions depend on the degree of power that can be leveraged in a relationship. We focus on the influence of this customer base competition on the supplier's reaction to the environmental disclosure signals in the customer base (Board, 2009).

As Emerson (1962) discusses, power and dependence are inversely related. As a customer becomes more dependent on a supplier (or the supplier becomes less dependent on a customer), that supplier becomes more powerful in that exchange relationship. Pfeffer and Salancik (1978) specifically highlight how dependence, and thus power, is related to the availability of scarce resources. Customers are likely dependent on a supplier when the supplier is also selling to that customers' competitors (i.e., as competition in the customer base increases). The more competing customers the supplier works with, the less likely the customers are able to find and switch to alternative sources of supply, making the supplier more difficult to replace. For example, Apple and Samsung both purchase glass from Corning Inc. for cell phones because of its superior quality, which means there are a small number of alternative sources for the phone makers to switch to. Thus, as competition increases in the customer base, supplier power also increases (Choi & Wu, 2009). In addition, customers sharing an identical supplier with their rivals often need to compete for capacity allocation to build their competitive advantage (Crook & Combs, 2007; Pulles et al., 2014). This also generates levers for the supplier to be in a stronger bargaining position lowering the dependence on any single customer and thus increasing the supplier's power.

As a supplier becomes more powerful, the supplier is more able to resist pressures or signals from the customers because the future costs imposed by competing customers is lower (Ahern, 2012; Chang et al., 2022). Hence, a supplier with more competition in the customer base should be less likely to be influenced by the signals from its customers' disclosure behavior, which could weaken the effect on the supplier's emissions reductions. In addition, when customers are aware they have a shared supplier, those customers may be less open about communicating expectations and sharing practices in environmental management with the shared supplier due to concerns of strategic information leakage to

their competitors through the common supplier (Muthulingam & Agrawal, 2016; Yan et al., 2020). As a result, a supplier with a more competitive customer base may also be subject to reduced signal strength and clarity of their customers' environmental management expectations. Together, we hypothesize:

**H3.** The negative association between customer base environmental disclosure and supplier GHG emissions is stronger when customer base competition is low.

## 4 | DATA AND MEASURES

### 4.1 | Data

To examine our hypotheses, we collect data from multiple sources. Following previous research (e.g., Bellamy et al., 2020; Gualandris et al., 2021), we collect environment-related data from the Bloomberg ESG dataset from 2010 to 2017. Bloomberg ESG captures firms' disclosure behavior (Huber & Comstock, 2017) as opposed to other ESG datasets that provide ESG performance ratings (e.g., MSCI ESG research). Additionally, Bloomberg ESG collects environmental data from multiple channels, including annual corporate responsibility and sustainability reports, regulatory filings, such as 10-Ks, corporate brochures and presentations, and website releases (Song et al., 2023). Bloomberg also collects information from direct communications with firms, such as through meetings, interviews, emails, and surveys (Bellamy et al., 2020). All of these channels enable Bloomberg to comprehensively evaluate firms' environmental disclosure behavior.

To identify customer-supplier linkages and competitor relationships, we use FactSet Revere data (hereafter FactSet). FactSet has been used to construct supply chain relationships in studies of risk management (Wang, Li, et al., 2021), supply chain volatility (Osadchiy et al., 2021), supply chain governance (Huang et al., 2020), and supply chain sustainability (Dai, Liang, et al., 2021). Additionally, compared to two commonly used supply chain relationship datasets, Compustat Segment and Bloomberg Supply Chain (SPLC), FactSet also provides data on a firm's competitors, which is used to construct one of our moderators, giving FactSet a unique fit for our study.

We collect climate-related innovation data from the USPTO (Hötte et al., 2022). To construct control variables, we collect data from Compustat, the U.S. Bureau of Economic Analysis, the United Nations Framework Convention on Climate Change (UNFCCC), and a

dataset on environmental non-governmental organizations (NGOs) provided by Partelow et al. (2020).

### 4.2 | Data cleaning

The goal of this study is to examine the effect of customer base environmental disclosure on a supplier's GHG emissions performance. We focus on tier-1 suppliers of manufacturing firms in our sampling because manufacturing firms generate more emissions compared with other downstream firms (e.g., retailers or distributors) (Goldstein et al., 2019; Riley, 2017) and likely receive most of the stakeholder pressure regarding emissions disclosure and reduction, which should affect their first-tier suppliers. To construct a sample of tier-1 suppliers, we first identify all manufacturers in Compustat in Standard Industrial Classification (SIC) codes 20–39 between 2010 and 2017 that appear as customers in FactSet. We then identify the tier-1 suppliers for that list of manufacturers, which results in a total of 12,457 suppliers. We match this list with Bloomberg ESG and identify 2165 suppliers. The rest of the data-cleaning process is summarized in Table 1. Note that suppliers in the trade, finance, service, and public administration sectors (SIC 50–99) are dropped in our final sample because suppliers in these industries are usually not targets associated with GHG emissions reduction. We also drop observations with missing supplier GHG emissions information and other missing data. Our final dataset contains 2434 supplier-year observations for 531 unique suppliers over eight years (2010–2017). There are 6561 unique customers for these suppliers, and, on average, each supplier has 27 customers in its customer base in any given year. Tables 2 and 3 present the industry by 2-digit SIC code and geographic distribution of the suppliers, respectively. We also provide two figures, Figures A1 and A2 in Appendix A, to present the industry and country distribution for customer-supplier dyads, respectively. As Figure A1 illustrates, customers come from a wider breadth of industries than do suppliers, which is expected given our sampling strategy and focus on tier-1 suppliers. This figure also highlights the importance of being able to capture inter-industry competition because of the breadth of industries, which we discuss when introducing our customer base competition measure. Additionally, as Figure A2 illustrates, customers also are headquartered in a wider breadth of countries than suppliers are. Most customer-supplier dyads in our sample are concentrated in North America, Europe, and East Asia. Thus, our sample represents suppliers that maintain a globally dispersed customer base.

TABLE 1 Data cleaning process.

Steps	Number of suppliers	Number of customers	Number of dyads
Preparation: Compile a list of targeted suppliers based on Compustat and FactSet data	12,457	21,718	193,372
Step 1: Identify suppliers in Bloomberg ESG	2165	11,283	61,035
Step 2: Drop suppliers in trade, finance, services, and public administration divisions (SIC 50–99)	1543	8861	40,064
Step 3: Drop observations with missing supplier GHG emissions data	807	7540	26,827
Step 4: Drop observations with missing values on the independent variable and moderators	734	7427	26,285
Step 5: Drop observations with missing values on the control variables	531	6561	21,291

Note: The table is based on the pooled data from our sample period.

### 4.3 | Measures

We have measures that capture the characteristics of the supplier and the supplier's customer base. Superscript *S* is used to denote variables measuring supplier information, and superscript *CB* is used to denote variables measuring customer base information.

#### 4.3.1 | Dependent variable

Supplier GHG emissions level,  $\ln\_emissions^S$ , is constructed using a supplier's total Scope 1 and Scope 2 GHG emissions collected from Bloomberg ESG (Adhikary et al., 2020). We use the total value of GHG emissions and log-transform the variable to adjust the distribution skewness (skewness = 7.88) following previous research (Azar et al., 2021; Muthulingam et al., 2022).

#### 4.3.2 | Independent variable

Our main independent variable, customer base environmental disclosure score ( $disclosure^{CB}$ ), captures the average environmental disclosure score across all the customers for each supplier. Each customer's environmental disclosure score is collected from Bloomberg ESG,<sup>4</sup> which measures the customer's degree and breadth of environmental disclosure based on various environmental indicators, such as the disclosure of emissions, energy, water, waste management, material, spills, environmental fines, environment-related investments and costs, certified sites, and operational policies.<sup>5</sup> Bloomberg collects this information from structured sources (e.g., emissions data and sustainability reports) and unstructured sources (e.g., press releases and news feeds). Each customer's environmental disclosure score, which is normalized

from 0 to 100 (Grewal et al., 2019), is a “standardized measure of the total number of data points disclosed by a firm relative to the total number of data points that are indicative of environmental performance and impacts for the industry in which the firm operates” (Bellamy et al., 2020, p. 906). Thus, “the score is tailored to different industry sectors” and each company is evaluated in terms of “the data that is relevant to its industry sector” (Lopez-de-Silanes et al., 2020, p. 228). Therefore, this environmental disclosure score addresses several methodological concerns regarding “lack of comprehensiveness, self-selection, and corporate greenwashing” that are common critiques of environmental disclosure measures (Bellamy et al., 2020, p. 907).

#### 4.3.3 | Moderators

##### *Customer base climate innovation*

To measure customer base climate innovation ( $\ln\_innovation^{CB}$ ), we use the average number of climate-related patents granted to customers in a given year (Aghion et al., 2020), calculated as follows:

$$\ln\_innovation_{it}^{CB} = \ln \left( \frac{\sum_{n=1}^{N_{it}} climate\_patents_{int}^C}{N_{it}} + 1 \right),$$

where  $N_{it}$  represents the number of customers of supplier *i* in year *t*, and  $climate\_patents_{int}^C$  denotes the number of climate-related patents granted to customer *n* of supplier *i* in year *t*. We define climate-related patents as those granted by the USPTO in year *t* and classified into the Cooperative Patent Classification (CPC) Y02 class, which captures technologies or applications for mitigation or adaptation against climate change. We log-transform the variable to reduce skewness (Aghion et al., 2020; Ben-Jebara & Modi, 2021).



TABLE 2 Supplier industry distribution.

SIC	Industry	No. of suppliers	Percent (%)
10	Metal Mining	6	1.13
13	Oil and Gas Extraction	8	1.51
15	Building Construction General Contractors and Operative Builders	5	0.94
16	Heavy Construction Other than Building Construction Contractors	8	1.51
20	Food and Kindred Products	26	4.90
21	Tobacco Products	6	1.13
22	Textile Mill Products	7	1.32
23	Apparel and Other Finished Products Made from Fabrics and Similar Materials	3	0.56
24	Lumber and Wood Products, Except Furniture	1	0.19
25	Furniture and Fixtures	2	0.38
26	Paper and Allied Products	10	1.88
27	Printing, Publishing, and Allied Industries	3	0.56
28	Chemicals and Allied Products	86	16.20
29	Petroleum Refining and Related Industries	13	2.45
30	Rubber and Miscellaneous Plastics Products	16	3.01
31	Leather and Leather Products	1	0.19
32	Stone, Clay, Glass, and Concrete Products	13	2.45
33	Primary Metal Industries	19	3.58
34	Fabricated Metal Products, Except Machinery and Transportation Equipment	7	1.32
35	Industrial and Commercial Machinery and Computer Equipment	72	13.56
36	Electronic and Other Electrical Equipment and Components, Except Computer Equipment	99	18.64
37	Transportation Equipment	46	8.66
38	Measuring, Analyzing, and Controlling Instruments; Photographic, Medical and Optical Goods; Watches and Clocks	31	5.84
39	Miscellaneous Manufacturing Industries	6	1.13
40	Railroad Transportation	1	0.19
42	Motor Freight Transportation and Warehousing	2	0.38
44	Water Transportation	2	0.38
45	Transportation by Air	4	0.75
47	Transportation Services	2	0.38
48	Communications	13	2.45
49	Electric, Gas, and Sanitary Services	13	2.45
	Total	531	100

Note: Column SIC represents the 2-digit SIC code.

### Customer base competition

We use the number of competitor relationships in a supplier's customer base to capture customer base

competition ( $competition^{CB}$ ). FactSet defines a competitor relationship when a source company discloses an entity as a competitor through trusted primary sources

TABLE 3 Supplier headquarter country distribution.

Country and Region	No. of suppliers	Percent (%)
Australia	9	1.69
Austria	3	0.56
Belgium	4	0.75
Canada	9	1.69
Switzerland	9	1.69
Germany	22	4.14
Denmark	6	1.13
Spain	9	1.69
Finland	9	1.69
France	30	5.65
United Kingdom	58	10.92
Greece	2	0.38
Italy	7	1.32
Japan	83	15.63
Korea, Republic of	19	3.58
Netherlands	9	1.69
Norway	5	0.94
New Zealand	1	0.19
Sweden	11	2.07
Taiwan	80	15.07
United States	146	27.50
Total	531	100

(Katona et al., 2018), including SEC filings, company websites, media outlets, and FactSet's proprietary studies (Wang, Li, et al., 2021). This method allows FactSet to record firms as competitors in the same primary industries (e.g., Denso (SIC 3714) and BorgWarner (SIC 3714) compete in engineered systems) as well as different industries (e.g., Cummins (SIC 3510) and Volkswagen (SIC 3711) compete in electrified power). Therefore, the measure developed by FactSet data has an advantage over using industries to define competitors because [1] firms in the same SIC industries may not be competitors as they can have different products and markets (e.g., CJ Foods (SIC 2099) and Cargill (SIC 2099) do not compete directly) and [2] firms in different industries can be competitors.

A common method to measure competition intensity is to consider the number of competitors, and the higher the number of competitors, the higher the competition intensity (Giachetti & Dagnino, 2014; Porter, 1980). We follow this logic to construct customer base competition ( $competition^{CB}$ ). Specifically,  $competition^{CB}$  measures the number of competitor relationships in a supplier's customer base scaled by the size of the customer base. It is computed by:

$$competition_{it}^{CB} = \frac{\sum_{n=1}^{N_{it}} \sum_{m=1}^{N_{it}} c_{mn}}{N_{it}},$$

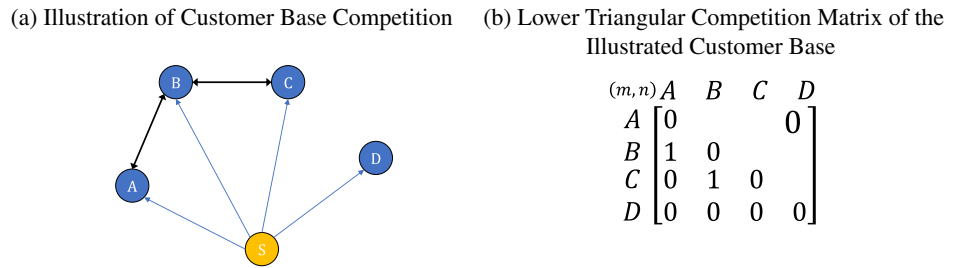
where  $N_{it}$  represents the number of customers of supplier  $i$  in year  $t$ .  $C_{it}$  is a  $N_{it} \times N_{it}$  network competition matrix with an element  $c_{mn}$  equal to one if customers  $m$  and  $n$  of supplier  $i$  are identified as competitors by FactSet in year  $t$ , and zero otherwise. To avoid double-counting, we transform  $C_{it}$  to be a lower triangular matrix (Kusiak & He, 1997). A simple example of customer base competition and competition matrix is illustrated in Figure 1. In this example, supplier S has four customers: Customers A, B, C, and D. Customers A and B are competitors, and customers B and C are competitors. Customer D is not a competitor of any member of the customer base. Thus,  $competition^{CB}$  in this example is calculated as  $\frac{2}{4} = 0.5$ .

#### 4.3.4 | Control variables

We control for multiple supplier and customer base-related characteristics. The operationalization for these measures can be found in Table 4. To control for a supplier's size and profitability, which can influence the supplier's GHG emissions, we use log-transformed supplier total assets,  $\ln\_total\_assets^S$ , and return on assets,  $ROA^S$ , respectively (Adhikary et al., 2020). We also control for financial leverage ( $leverage^S$ ) because a supplier's financial leverage may influence the supplier's environmental decisions (Brammer & Pavelin, 2006). We use inventory turnover ( $inventory\_turnover^S$ ) to control for a supplier's operational efficiency, which can influence the supplier's energy efficiency and thus emissions (Plambeck, 2012). As innovation can drive emissions reduction (Fernández et al., 2018; Miśkiewicz, 2021), we control for a supplier's innovation using the supplier's research and development intensity ( $R\&D\_intensity^S$ ) and the supplier's climate innovation patents ( $\ln\_innovation^S$ ).

We also control for a supplier's industry and country heterogeneity. First, a supplier's position in a supply chain can affect its level of emissions because downstream industries typically emit less GHG emissions (Shapiro, 2021) and receive more consumer attention (Li & Zhou, 2017). Thus, to account for this effect, we control for the upstreamness of the supplier's industry ( $industry\_upstreamness^S$ ). Second, we control for the supplier industry's direct GHG emissions levels using Scope 1 emissions ( $\ln\_industry\_scope1^S$ ). Third, following Jira and Toffel (2013) and Villena and Dhanorkar (2020), we control for the Kyoto Protocol status of a supplier's country ( $Kyoto\_status^S$ ). We also control for the environmental

**FIGURE 1** Illustration of the construction of customer base competition. The double-headed arrows in panel (a) represent competitor relationships, and the single-headed arrows represent customer-supplier relationships.



NGO density (*environmental\_NGO<sup>S</sup>*) in a supplier's country.

Last, we control for multiple characteristics of a supplier's customer base, including the number of customers in the supplier's customer base (*size<sup>CB</sup>*) and the log-transformed customers' average total assets (*ln\_total\_assets<sup>CB</sup>*). Additionally, we control for the average length of the customer-supplier relationship (*relationship\_length<sup>CB</sup>*) to account for the relationship strength between a supplier and its customers (Autry & Golicic, 2010). Table 5 presents the summary of descriptive statistics and the correlation matrix of the variables used in our main analysis.

## 5 | MODELS AND RESULTS

### 5.1 | Regression models

To test our hypotheses, we estimate a panel fixed-effects model with clustered robust standard errors at the supplier level and supplier and year fixed effects. The full model is shown in Equation (1).

$$\begin{aligned} \ln\_emissions_{it}^S = & \beta_0 + \beta_1 disclosure_{it}^{CB} + \beta_2 \ln\_innovation_{it}^{CB} \\ & + \beta_3 competition_{it}^{CB} + \beta_4 disclosure_{it}^{CB} \\ & \times \ln\_innovation_{it}^{CB} + \beta_5 disclosure_{it}^{CB} \\ & \times competition_{it}^{CB} + X_{it}\gamma + \sigma_i + \tau_t + \varepsilon_{it} \end{aligned} \quad (1)$$

where  $i$  indexes supplier and  $t$  indexes year.  $X_{it}$  represents the vector of control variables discussed in section 4.3.4.  $\sigma_i$  and  $\tau_t$  denote supplier and year fixed effects, respectively, and  $\varepsilon_{it}$  is the error term. We cluster standard errors at the supplier level to account for heteroskedasticity and autocorrelation that cannot be fully accounted for by the fixed effects (Cameron & Miller, 2015).

### 5.2 | Results

Table 6 summarizes the results of the main analysis. Prior to discussing the results of the hypotheses, we report the effects of the control variables. In Model 1 of Table 6, the coefficient for supplier total assets is positive

and significant ( $\beta = .466$ ,  $p$ -value  $< .001$ ). This result is consistent with the literature showing that larger firms typically emit more GHG emissions. Supplier ROA is negative and marginally significant ( $\beta = -.216$ ,  $p$ -value  $= .059$ ), suggesting that a profitable supplier may have more resources to reduce emissions (Adhikary et al., 2020). We also find a negative and marginally significant relationship between supplier financial leverage and supplier GHG emissions ( $\beta = -.240$ ,  $p$ -value  $= .083$ ). As expected, the supplier's industry upstreamness is positive and significant ( $\beta = .387$ ,  $p$ -value  $= .008$ ). At the customer base level, we find that customer base total assets has a marginally significant positive effect on a supplier's emissions level ( $\beta = .021$ ,  $p$ -value  $= .095$ ).

Model 1 is used to evaluate H1. We find that the effect of customer base environmental disclosure on supplier GHG emissions is negative and significant ( $\beta_1 = -.003$ ,  $p$ -value  $= .004$ ). Therefore, H1 is supported. The coefficient suggests that an extra unit increase in customer base environmental disclosure is, on average, associated with a 0.3% decrease in a supplier's GHG emissions. For suppliers who generate an average level of emissions in our sample, an increase of one standard deviation in customer base environmental disclosure is associated with 163.7 thousand metric tons of carbon dioxide equivalent (CO<sub>2</sub>e) reduction per year, indicating a nontrivial impact.<sup>6</sup>

Model 2 is used to evaluate H2. The coefficient of the interaction term between customer base environmental disclosure and customer base climate innovation is positive and marginally significant ( $\beta = .0006$ ,  $p$ -value  $= .062$ ), which is contrary to our prediction in H2. This result suggests that customer base climate innovation may weaken the role of customer base environmental disclosure in supplier emissions reduction. However, the interaction term is found to be statistically insignificant in the full model (Model 4) ( $\beta = .0005$ ,  $p$ -value  $= .129$ ). The discrepancy between Model 2 and Model 4 may be attributed to the multicollinearity in Model 4. As both models fail to support H2, we examine and discuss this finding in detail in Section 5.4.

Model 3 is used to evaluate H3. We find the coefficient of the interaction term between customer base environmental disclosure and customer base competition is

TABLE 4 Variable construction.

Variable	Description	Category	Operationalization	Data source	Reference
<i>ln_emissions<sup>S</sup></i>	Supplier GHG emissions	Dependent	Log-transformed a supplier's total Scope 1 and Scope 2 GHG emissions	Bloomberg ESG	Azar et al. (2021)
<i>disclosure<sup>CB</sup></i>	Customer base environmental disclosure	Independent	Average environmental disclosure scores across all of the customers	Bloomberg ESG	Bellamy et al. (2020)
<i>ln_innovation<sup>CB</sup></i>	Customer base climate innovation	Moderator	Log-transformed average number of climate-related patents granted to the customers	USPTO	Aghion et al. (2020); Ben-Jebara and Modi (2021)
<i>competition<sup>CB</sup></i>	Customer base competition	Moderator	Number of competing pairs in a customer base scaled by the size of the customer base	FactSet	Adapted from Giachetti and Dagnino (2014)
<i>ln_total_assets<sup>S</sup></i>	Supplier total assets	Control	Log-transformed total assets of a supplier	Compustat	Mishra et al. (2013)
<i>ROA<sup>S</sup></i>	Supplier return on assets	Control	Ratio of net income to total assets	Compustat	Dong et al. (2020)
<i>leverage<sup>S</sup></i>	Supplier financial leverage	Control	Ratio of total debt to total assets	Compustat	Serpa and Krishnan (2018)
<i>inventory_turnover<sup>S</sup></i>	Supplier inventory turnover	Control	Ratio of cost of goods sold to inventory	Compustat	Wu et al. (2019)
<i>R&amp;D_intensity<sup>S</sup></i>	Supplier R&D intensity	Control	Ratio of R&D expenditure to total sales	Compustat	Song et al. (2023)
<i>ln_innovation<sup>S</sup></i>	Supplier climate innovation	Control	Log-transformed number of climate-related patents granted to a supplier	USPTO	Aghion et al. (2020); Ben-Jebara and Modi (2021)
<i>industry_upstreamness<sup>S</sup></i>	Upstreamness of supplier's industry	Control	Following the method introduced by Antràs et al. (2012) <sup>a</sup>	U.S. Bureau of Economic Analysis	Antràs et al. (2012)
<i>ln_industry_scope1<sup>S</sup></i>	Direct GHG emissions levels of supplier's industry	Control	Log-transformed average Scope 1 emissions of all firms in a supplier's industry	Bloomberg ESG	Azar et al. (2021)
<i>Kyoto_status<sup>S</sup></i>	Kyoto Protocol status of supplier's country	Control	A binary variable equal to one if the country is in the Kyoto Protocol's Annex I and has ratified, approved, accepted, and accessed the protocol	UNFCCC	Jira and Toffel (2013); Villena and Dhanorkar (2020)
<i>environmental_NGO<sup>S</sup></i>	Environmental NGO density of supplier's country	Control	Number of environmental NGOs per million population in a supplier's country	Partelow et al. (2020)	Jira and Toffel (2013); Villena and Dhanorkar (2020)
<i>size<sup>CB</sup></i>	Customer base size	Control	Number of customers in a customer base	FactSet	Mishra et al. (2013)



TABLE 4 (Continued)

Variable	Description	Category	Operationalization	Data source	Reference
$\ln\_total\_assets^{CB}$	Customer base average total assets	Control	Log-transformed average total assets of the customers	Compustat	Mishra et al. (2013)
$relationship\_length^{CB}$	Length of customer-supplier relationship	Control	Average length of the customer-supplier relationship in a customer base	FactSet	Autry and Golovic (2010)

<sup>a</sup>Antràs et al. (2012) use input–output tables from Industry Economic Accounts Data to construct the average distance to an end market for an industry. A higher value represents the supplier's industry is further from the final use (Antràs et al., 2012).

positive and significant ( $\beta = .005$ ,  $p$ -value = .009), supporting H3. Likewise, the coefficient of this interaction term in Model 4 is positive and significant ( $\beta = .005$ ,  $p$ -value = .014). These findings show that a high level of competition among a supplier's customers may benefit the supplier in terms of bargaining power, making the supplier less vulnerable and sensitive to signals and pressures in addressing environmental concerns and emissions reduction from the customer base.

We present the interaction plots for the two moderators in Figure 2 based on Models 2 and 3. In Figure 2, the low and high values for each moderator are the 10th (low) and 90th (high) percentiles, respectively, and customer base environmental disclosure ranges from the 10th to the 90th percentiles. Panel (a) shows that although the effects of customer base environmental disclosure on a supplier's emissions level are negative for high and low levels of customer base climate innovation, the magnitude of the effect is stronger when customer base climate innovation is lower. Panel (b) shows that the effect of customer base environmental disclosure on supplier emissions level is negative when competition in the customer base is low (at the 10th percentile), but that effect becomes positive when competition is high (at the 90th percentile).

We present the marginal effects plots of the two moderators in Figure 3 based on Model 2 and 3. These plots demonstrate the marginal effects of customer base environmental disclosure on supplier GHG emissions and their statistical significance across the range of customer base climate innovation and competition. The two vertical lines on each plot represent the 25th and 75th percentiles of customer base climate innovation and competition. Panel (a) shows that the marginal effect becomes weaker as customer base climate innovation increases, and when customer base climate innovation is greater than the 63rd percentile, the marginal effect is no longer significant. Panel (b) shows the marginal effect is negative and significant when customer base competition is low. The marginal effect also

becomes weaker as competition increases, and when the competition is greater than the 62nd percentile, the marginal effect is no longer significant.

### 5.3 | Robustness checks

In the following subsections, we perform several additional analyses to assess the robustness of our main results.

#### 5.3.1 | Lagged effect of customer base environmental disclosure

One potential endogeneity concern with our analysis is that customers' environmental disclosure decisions may be driven by supplier GHG emissions (reverse causality), or more specifically that customers with green suppliers may be more likely to engage in environmental disclosure. Although it is unlikely that a single supplier's emissions performance can drive all of its customers' environmental disclosure decisions, we conduct several tests to rule out this concern.

First, we follow Ball et al. (2018) and Khuntia et al. (2018) and estimate a panel fixed-effects model with standard errors clustered at the supplier level using customer base disclosure in year  $t + 1$  ( $leaded\_disclosure^{CB}$ ) as the dependent variable, supplier GHG emissions in year  $t$  as the independent variable, and all the moderators and controls used in the main analysis in year  $t$ . Results show the coefficient of supplier GHG emissions is insignificant ( $p$ -value = .308).

Second, we follow Wani et al. (2021) and use customer base environmental disclosure in year  $t$  as the dependent variable and the difference between supplier GHG emissions in year  $t$  and year  $t - 1$  ( $\Delta emissions^S$ ) as the independent variable. We include the moderators and controls used in the main analysis in year  $t$  and we estimate the same fixed-effects model with standard

TABLE 5 Descriptive statistics and correlation matrix.

	Mean	S.D.	Unit	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1) <i>ln_emissions<sup>S</sup></i>	6.26	2.10	Ln(thousand metric tons)	1.00																
(2) <i>disclosure<sup>CB</sup></i>	37.57	13.51	Point	-0.09 (0.00)	1.00															
(3) <i>ln_innovation<sup>CB</sup></i>	5.05	1.65	Ln(number of patents)	-0.06 (0.00)	0.22 (0.00)	1.00														
(4) <i>competition<sup>CB</sup></i>	0.51	0.63	-	-0.02 (0.29)	0.09 (0.00)	0.18 (0.00)	1.00													
(5) <i>ln_total_assets<sup>S</sup></i>	9.21	1.57	Ln (Millions of US Dollars)	0.71 (0.00)	-0.17 (0.00)	-0.00 (0.81)	0.06 (0.00)	1.00												
(6) <i>ROA<sup>S</sup></i>	0.05	0.07	-	-0.10 (0.00)	-0.04 (0.07)	-0.08 (0.00)	0.04 (0.07)	-0.01 (0.80)	1.00											
(7) <i>leverage<sup>S</sup></i>	0.24	0.15	-	0.22 (0.00)	-0.14 (0.00)	-0.10 (0.00)	-0.06 (0.00)	0.16 (0.00)	-0.19 (0.00)	1.00										
(8) <i>inventory_turnover<sup>S</sup></i>	8.97	18.25	-	-0.01 (0.63)	0.02 (0.27)	0.01 (0.77)	-0.01 (0.60)	0.02 (0.38)	-0.01 (0.54)	-0.00 (0.90)	1.00									
(9) <i>R&amp;D_intensity<sup>S</sup></i>	2.30	9.81	-	0.11 (0.00)	0.03 (0.12)	0.14 (0.00)	0.02 (0.43)	0.09 (0.00)	0.01 (0.51)	-0.09 (0.00)	-0.04 (0.07)	1.00								
(10) <i>ln_innovation<sup>S</sup></i>	2.76	2.41	Ln(number of patents)	0.27 (0.00)	-0.12 (0.00)	0.25 (0.00)	0.12 (0.43)	0.52 (0.00)	-0.05 (0.51)	-0.02 (0.00)	0.02 (0.31)	0.14 (0.00)	1.00							
(11) <i>industry_upstreamness<sup>S</sup></i>	2.03	0.49	-	0.40 (0.00)	0.05 (0.01)	-0.12 (0.00)	-0.05 (0.02)	0.12 (0.00)	-0.04 (0.08)	0.11 (0.00)	-0.09 (0.00)	-0.07 (0.00)	-0.08 (0.00)	1.00						
(12) <i>ln_industry_scope1<sup>S</sup></i>	6.32	1.57	Ln(thousand metric tons)	0.51 (0.00)	-0.03 (0.17)	-0.16 (0.00)	-0.08 (0.00)	0.24 (0.00)	-0.04 (0.03)	0.15 (0.00)	0.07 (0.00)	-0.08 (0.00)	-0.04 (0.05)	0.59 (0.00)	1.00					
(13) <i>Kyoto_status<sup>S</sup></i>	0.52	0.50	-	-0.01 (0.50)	0.12 (0.00)	-0.01 (0.55)	-0.11 (0.00)	-0.00 (0.92)	-0.17 (0.00)	-0.13 (0.04)	0.04 (0.00)	-0.11 (0.00)	-0.12 (0.00)	0.08 (0.00)	0.10 (0.00)	1.00				

TABLE 5 (Continued)

	Mean	S.D.	Unit	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(14) <i>environmental_NGO<sup>S</sup></i>	0.43	0.35	Number of NGOs per million population	−0.08	−0.12	−0.12	0.06	−0.04	−0.00	−0.02	0.02	−0.15	−0.09	0.06	0.05	0.34	1.00			
(15) <i>size<sup>CB</sup></i>	27.29	30.19	Number of firms	(0.00)	(0.00)	(0.00)	(0.00)	(0.04)	(0.82)	(0.30)	(0.26)	(0.00)	(0.00)	(0.00)	(0.02)	(0.00)				
(16) <i>ln_total_assets<sup>CB</sup></i>	10.26	1.28	Ln (Millions of US Dollars)	0.18	−0.08	0.22	0.38	0.40	−0.03	−0.07	0.03	0.10	0.43	−0.04	−0.04	−0.02	0.08	1.00		
(17) <i>relationship_length<sup>CB</sup></i>	1.39	0.97	Year	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.14)	(0.00)	(0.16)	(0.00)	(0.00)	(0.06)	(0.04)	(0.46)	(0.00)			
				−0.09	0.44	0.41	0.21	−0.10	−0.05	−0.07	0.11	0.00	−0.06	−0.03	−0.01	0.16	0.10	0.07	1.00	
				(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)	(0.00)	(0.00)	(0.98)	(0.00)	(0.11)	(0.72)	(0.00)	(0.00)	(0.00)		
				0.11	−0.06	−0.03	0.30	0.15	0.06	0.01	−0.06	0.00	0.09	−0.04	−0.03	−0.23	−0.07	0.08	−0.05	1.00
				(0.00)	(0.00)	(0.17)	(0.00)	(0.00)	(0.00)	(0.60)	(0.00)	(0.92)	(0.00)	(0.08)	(0.16)	(0.00)	(0.00)	(0.00)	(0.02)	

Note: *p*-value of the correlations between variables in parentheses.

errors clustered at the supplier level. Results show the coefficient of  $\Delta emissions^S$  is not significant (*p*-value = .147). The results of these two tests are presented in Appendix B, Table B1.

Last, we also examine the concern by lagging the right-hand side variables by one year and re-estimating our main model. The results are presented in Table B2 in Appendix B and are directionally consistent with our main results. It is worth noting that the interaction effect between customer base environmental disclosure and climate innovation displays a higher level of statistical significance in model Robust 1–2 (*p*-value = .009). Further, the interaction now becomes significant in the full model Robust 1–4 (*p*-value = .030). These findings may suggest a possible lagged moderation effect of customer base climate innovation.

### 5.3.2 | Self-selection biases

One major reason for our sample reduction is the reporting of suppliers' GHG emissions, which is typically voluntary, especially in the United States (Villena & Dhanorkar, 2020). Therefore, concerns about self-selection biases may arise. To examine this potential issue, we estimate a Heckman two-stage selection model (Heckman, 1979). We use a probit model to estimate the suppliers' GHG emissions disclosure decisions with whether the supplier discloses GHG emissions (*disclosing\_GHG<sup>S</sup>*) as the dependent variable. To meet the exclusion restriction requirement (Cameron & Trivedi, 2010), we use the instrument, *emissions\_disclosure\_peers*, which measures the percentage of firms in a supplier's industry (identified by 2-digit SIC code) and country disclosing emissions. This variable is likely to impact a supplier's emissions disclosure decision but not directly influence how the supplier responds to its customers' environmental disclosure (Villena & Dhanorkar, 2020). The results of the first-stage model are presented in Appendix C, Table C1. We then calculate the inverse Mills ratio (IMR) from the first-stage result and include IMR as a selection-correction term in the second-stage model. Appendix C, Table C2 presents the results of the second-stage model. The results are consistent with our main results, and IMR is not significant in the model.

### 5.3.3 | Alternative measure for customer base competition

In our measure for customer base competition, we consider the number of competitor relationships in the customer base scaled by the size of the customer base. We

TABLE 6 Main results.

Dependent variable: <i>ln_emissions<sup>S</sup></i>	Model 1		Model 2		Model 3		Model 4	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
<i>disclosure<sup>CB</sup></i>	−0.003**	(0.001)	−0.005**	(0.002)	−0.004**	(0.001)	−0.006**	(0.002)
<i>ln_innovation<sup>CB</sup></i>	−0.004	(0.010)	−0.020	(0.014)	−0.002	(0.010)	−0.015	(0.013)
<i>competition<sup>CB</sup></i>	0.031	(0.030)	0.030	(0.030)	−0.175*	(0.089)	−0.161 <sup>†</sup>	(0.087)
<i>disclosure<sup>CB</sup> x ln_innovation<sup>CB</sup></i>			0.001 <sup>†</sup>	(0.000)			0.000	(0.000)
<i>disclosure<sup>CB</sup> x competition<sup>CB</sup></i>					0.005**	(0.002)	0.005*	(0.002)
<i>ln_total_assets<sup>S</sup></i>	0.466**	(0.075)	0.464**	(0.075)	0.467**	(0.075)	0.464**	(0.075)
<i>ROA<sup>S</sup></i>	−0.216 <sup>†</sup>	(0.114)	−0.215 <sup>†</sup>	(0.114)	−0.201 <sup>†</sup>	(0.114)	−0.201 <sup>†</sup>	(0.114)
<i>leverage<sup>S</sup></i>	−0.240 <sup>†</sup>	(0.138)	−0.245 <sup>†</sup>	(0.138)	−0.215	(0.139)	−0.221	(0.139)
<i>inventory_turnover<sup>S</sup></i>	0.000	(0.002)	0.000	(0.002)	0.000	(0.002)	0.000	(0.002)
<i>R&amp;D_intensity<sup>S</sup></i>	0.001	(0.001)	0.001	(0.001)	0.000	(0.001)	0.001	(0.001)
<i>ln_innovation<sup>S</sup></i>	0.002	(0.005)	0.003	(0.005)	0.003	(0.005)	0.003	(0.005)
<i>industry_upstreamness<sup>S</sup></i>	0.387**	(0.145)	0.393**	(0.145)	0.395**	(0.145)	0.399**	(0.145)
<i>ln_industry_scope1<sup>S</sup></i>	−0.002	(0.035)	−0.000	(0.035)	−0.001	(0.035)	0.000	(0.035)
<i>Kyoto_status<sup>S</sup></i>	−0.108	(0.143)	−0.121	(0.136)	−0.072	(0.164)	−0.084	(0.157)
<i>environmental_NGO<sup>S</sup></i>	0.584	(0.617)	0.534	(0.616)	0.558	(0.611)	0.520	(0.611)
<i>size<sup>CB</sup></i>	0.001	(0.001)	0.001	(0.001)	0.001	(0.001)	0.001	(0.001)
<i>ln_total_assets<sup>CB</sup></i>	0.021 <sup>†</sup>	(0.013)	0.020	(0.013)	0.023 <sup>†</sup>	(0.013)	0.022 <sup>†</sup>	(0.013)
<i>relationship_length<sup>CB</sup></i>	0.004	(0.010)	0.004	(0.010)	0.005	(0.010)	0.005	(0.010)
Constant	1.011	(0.732)	1.128	(0.733)	1.001	(0.731)	1.096	(0.731)
Supplier fixed effects	Y		Y		Y		Y	
Year fixed effects	Y		Y		Y		Y	
Observations	2434		2434		2434		2434	
R-squared	0.102		0.104		0.107		0.108	
Number of suppliers	531		531		531		531	

Note: Robust standard errors, clustered at the supplier level, in parentheses.

<sup>†</sup>*p* < .10;

\**p* < .05; \*\**p* < .01.

develop an alternative measure *competition\_alternative<sup>CB</sup>*, which computes the number of competitor relationships scaled by the maximum possible customer pairs in the customer base. The measure is calculated as:

$$competition\_alternative_{it}^{CB} = \frac{\sum_{n=1}^{N_{it}} \sum_{m=1}^{N_{it}} c_{mn}}{\frac{1}{2} N_{it} (N_{it} - 1)}.$$

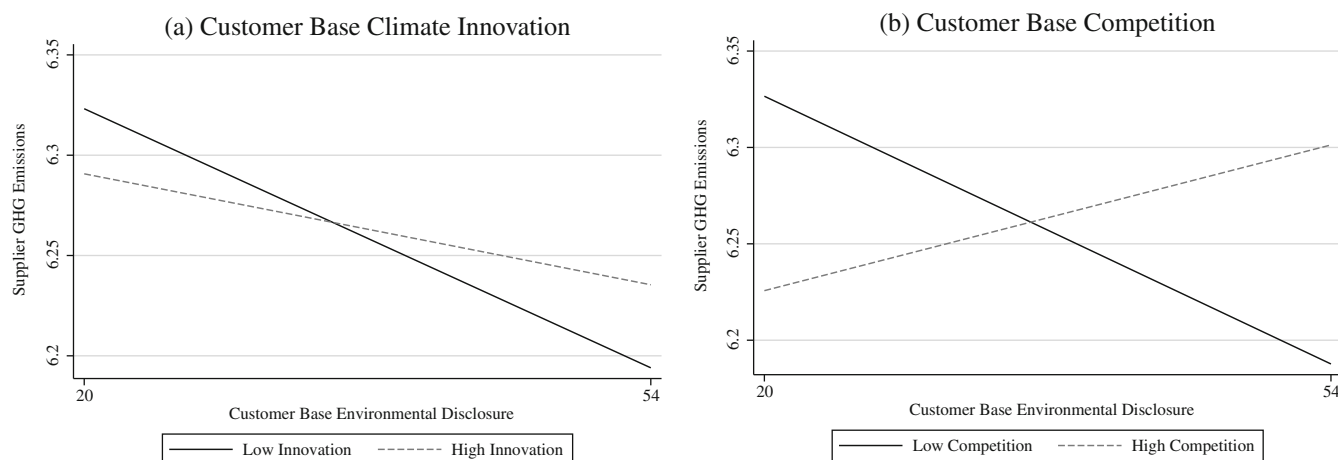
Using the same example in Figure 1, *competition\_alternative<sup>CB</sup>* would be calculated as  $\frac{2}{6} = \frac{1}{3}$ .<sup>7</sup> We use this alternative measure to replace *competition<sup>CB</sup>* and rerun the main model. The results, provided in Table D1 in Appendix D, are directionally consistent with our main model results. Despite the lower statistical significance level of the customer base competition interaction effect in model Robust 3–3 (*p*-value = .038)

compared to the main results, it still shows a positive association with a supplier's GHG emissions, which supports our main finding.

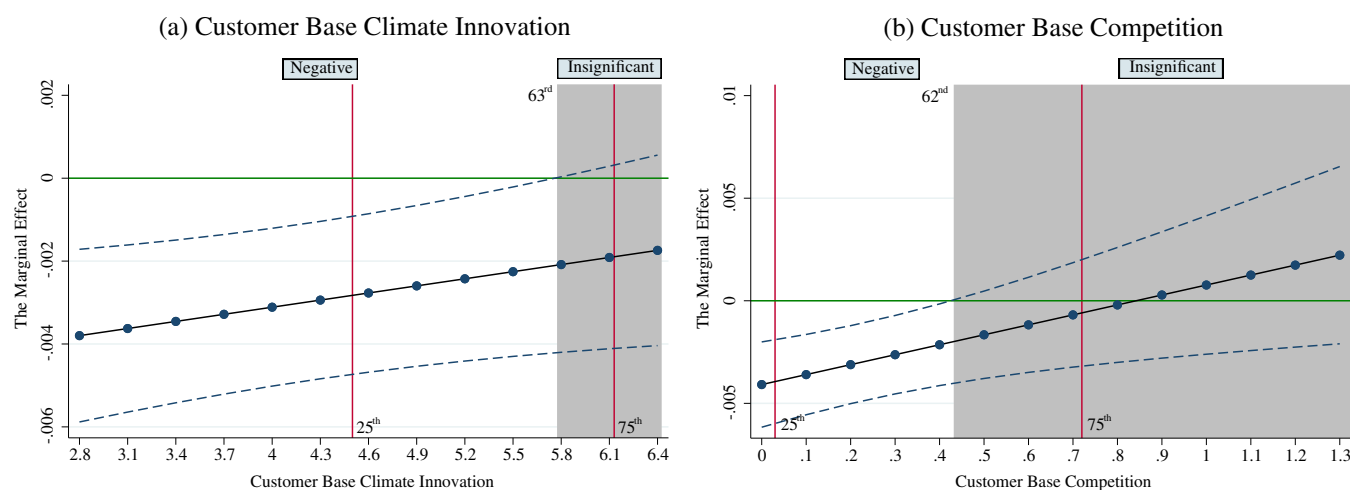
### 5.3.4 | Omitted variables

Omitted variables may bias our estimation as the relationship between customer base environmental disclosure and supplier GHG emissions reduction may be driven by unobservable characteristics that affect both measures. For example, customers' major stakeholders (e.g., shareholders) may push both the customers and the customers' suppliers to be more environmentally transparent and responsible (Dai, Liang, et al., 2021). To address this concern, we select three instruments—the customer base social disclosure score and the average





**FIGURE 2** The moderating effect of customer base climate innovation and competition. Customer base environmental disclosure ranges from the 10th to the 90th percentiles. The high and low customer base climate innovation and competition refer to the 90th percentile and the 10th percentile, respectively.



**FIGURE 3** Marginal effects plots for the moderating effects of customer base climate innovation and competition. Moderators on the x-axis are set from the 10th to the 90th percentiles of the variables. The two vertical lines represent the 25th and 75th percentiles of customer base climate innovation (panel (a)) and competition (panel (b)). The dashed lines represent the 95% confidence interval. The gray areas indicate where the marginal effects are insignificant.

customer base environmental disclosure of other firms in a supplier's industry and country. The details of the instrument selection and estimation process are presented in Appendix E. We first conduct multiple endogeneity tests. The result of the Wooldridge's (1995) robust score test ( $p$ -value = .707) fails to reject the null hypothesis that customer base environmental disclosure is exogenous (Huang & Sudhir, 2021). Likewise, the results of the Durbin–Wu–Hausman (DWH) test (Durbin score  $p$ -value = .561, Wu–Hausman test  $p$ -value = .610) also fail to reject the null exogenous hypothesis (Lu et al., 2018). Despite these test results, we employ a two-stage least square (2SLS) regression and present their results in Table E2 in Appendix E. The results of the second-stage

regression models are directionally consistent with our main results, although some display lower levels of statistical significance, which is expected for 2SLS estimators. Additionally, our instruments pass the under-identification, over-identification, and weak-identification tests, suggesting the exogeneity and validity of our instruments. Details of the first-stage regression of 2SLS and instrument test results are also provided in Appendix E.

### 5.3.5 | Dyad-level analysis

Our main analysis shows that customers' collective disclosure behaviors significantly influence a supplier's

emissions reduction. This finding is consistent with the literature showing that a supplier's environmental decisions may be influenced by the collective decisions and behaviors of its customers (e.g., Jira & Toffel, 2013; Villena & Dhanorkar, 2020). In this robustness check, we conduct a dyad-level analysis to examine the robustness of our main results and to address customer- and dyad-level heterogeneity. In addition, the dyad-level analysis allows us to cluster errors at both the customer and the supplier levels, reducing the concern of underestimated standard errors (Cameron et al., 2011).

We use an individual customer's environmental disclosure score as the independent variable, and we keep the dependent variable, moderators, and control variables consistent with those used in the main analysis. We include two additional dyad-level characteristics as control variables, *same\_industry<sup>D</sup>* and *same\_country<sup>D</sup>*, which measure whether a supplier and its customer are from the same industry (identified by 4-digit SIC) or country, respectively. We control for both supplier and customer fixed effects as well as year fixed effects. In addition, we use the two-way clustering estimator, which can address the concern of correlated standard errors among shared suppliers and customers (Cameron et al., 2011). Appendix F, Table F1 presents the results of the dyad-level analysis, which are directionally consistent with our main model results. Specifically, we find that the main effect has a lower level of statistical significance ( $p$ -value = .095), but the interaction terms for customer base climate innovation and competition display higher levels of significance ( $p$ -value < .001 and  $p$ -value = .002, respectively). Despite these changes, the results remain largely consistent with our main findings.

## 5.4 | Extension—Further examining customer base climate innovation

Our results for H2 show that customer base climate innovation possibly attenuates the relationship between customer base environmental disclosure and supplier GHG emissions. In this section, we explore several possibilities for this unexpected result.<sup>8</sup>

First, we argue that a high level of customers' climate-related patents may serve as a high-quality signal of these customers' commitment to addressing climate change and thus strengthening the signal created by environmental disclosure. However, it is possible that the two signals are substitutable to suppliers rather than complementing each other. If this conjecture holds, we would observe that customer base climate innovation should have a direct impact on the supplier's GHG emissions as well. However, in Model 1 of Table 6, we find an

insignificant effect of customer base climate innovation on supplier GHG emissions ( $p$ -value = .728). Given the significantly high correlation between customer base environmental disclosure and climate innovation, we drop customer base environmental disclosure and re-estimate our main model. The effect of customer base climate innovation on a supplier's GHG emissions remains insignificant ( $p$ -value = .616), suggesting that customer base climate innovation may not necessarily serve as a direct signal for a supplier to reduce emissions.

Second, it is also possible that customer base climate innovation affects how a supplier reacts to the signal created by environmental disclosure. For example, customers with a high level of green patents may have stringent supplier selection and evaluation requirements and hence already work with low emissions-intensive suppliers, or green technologies and best practices shared by or spilled over from these highly climate-innovative customers have already helped suppliers reduce emissions (Angell & Klassen, 1999; Corbett, 2006; Corbett & Kirsch, 2001; Wilhelm & Villena, 2021). If this is the case, a supplier with a highly climate-innovative customer base may already emit less than its counterparts with low climate-innovative customer bases. Thus, the supplier would be less likely to react to the signals because it has limited room to reduce emissions further. If this conjecture holds, we would likely observe that the suppliers with highly climate-innovative customers have lower emissions intensities than their industry counterparts with low climate-innovative customers.

To examine this, we use propensity score matching (PSM) to match suppliers who work with highly climate-innovative customers with their counterparts who work with low climate-innovative customers and compare their emissions intensities. We create a dummy variable (*high<sup>S</sup>*) based on a supplier's customer base climate innovation level in the supplier's industry (identified by 2-digit SIC). *High<sup>S</sup>* is equal to one if the supplier's customer base climate innovation is in the top 25th percentile of the supplier's industry in a year and zero for the bottom 25th. Next, we use PSM to match the two groups.<sup>9</sup> The matching covariates include all the control variables in the main analysis as well as the year and industry (identified by 2-digit SIC) dummies. We match each supplier in the *high<sup>S</sup>* = 1 group with one supplier in the *high<sup>S</sup>* = 0 group and drop observations without matches. The paired t-test results based on the matched sample of 168 pairs show that supplier GHG emissions intensity (i.e., the ratio of GHG emissions to total assets) of the *high<sup>S</sup>* = 1 group is less than that of the *high<sup>S</sup>* = 0 group at 0.05 significance level ( $p$ -value = .038). We rerun our main model with supplier GHG emissions intensity (*emissions\_intensity<sup>S</sup>*) as the dependent variable and *high<sup>S</sup>*

as the independent variable for the matched sample and include year and industry fixed effects. The results, provided in Table G1 in Appendix G, show the coefficient of  $high^S$  is negative and significant ( $\beta = -.059$ ,  $p\text{-value} = .031$ ), suggesting that the GHG emissions intensity of suppliers with high customer base climate innovation is significantly lower than that of the suppliers with low customer base climate innovation. Hence, these suppliers, who work with high climate innovation customers, may be less likely to react further to the disclosure's signaling effect.

Finally, suppliers are also less likely to react to the signal created by environmental disclosure if both the customers and their suppliers are climate-innovative. This is because when supply chains are making innovative, green products with a high level of climate innovation from both customers and their suppliers, the supply chain can be already efficient and transparent in communication and coordination for environmental performance improvement throughout the supply chain, reducing the need for and impact of the signaling effect (Angell & Klassen, 1999; Corbett, 2006; Corbett & Kirsch, 2001; Wilhelm & Villena, 2021). To test this conjecture, we identify two groups of suppliers based on their climate innovation level and compare the moderating effect of customer base climate innovation. If our arguments hold, we should observe a stronger moderating effect of customer base innovation for suppliers that are more innovative in climate-related knowledge and technologies. We separate suppliers into high-innovation and low-innovation groups according to their climate patents granted during the time window of our analysis by calculating each supplier's average annual number of climate patents and calculating the percentile rank by industry (identified by the 2-digit SIC code). We define the "low-innovation group" to include the suppliers whose average climate patent is below the first quartile in their industry and the "high-innovation group" to include the suppliers whose average climate patent is above the third quartile in their industry. We rerun the model for H2, Model 2, for each group. The results are presented in Table G2 in Appendix G. The estimated coefficient of the interaction term between customer base environmental disclosure and climate innovation for the high-innovation group is positive and significant, consistent with our main analysis. Interestingly, the coefficient of interest for the low-innovation group is negative and significant. The result of the generalized Hausman-test for cross-estimators (Weesie, 2000) shows that the coefficients are significantly different for the low- and high-innovation groups ( $p\text{-value} = .002$ ). This result suggests that when suppliers of highly climate-innovative customers are also climate-innovative, customer base disclosure also has less

of a signaling effect, possibly because such supply chains are already efficient in communication and coordination regarding environmental performance improvement.

In sum, our extended analyses suggest that the counterintuitive result of H2 may not be due to customer base climate innovation potentially serving as a direct signal for suppliers to reduce emissions, substituting the signaling effect of environmental disclosure. Instead, we find the effect may be because suppliers who work with highly climate-innovative customers may already be efficient in environmental performance improvement for the reasons discussed above and are therefore less likely to react further.

## 6 | DISCUSSION AND CONCLUSION

Given the importance of reducing supply chain GHG emissions to achieve carbon neutrality, this study uses signaling theory to examine the influence of customer base environmental disclosure on a supplier's emissions. In contrast to the literature that suggests environmental disclosure-intensive customers may outsource emissions to their suppliers (Yang et al., 2021), we find that customer base disclosure may signal the importance of environmental transparency and responsibility for customers, motivating the supplier to reduce emissions. We also find that customer base climate innovation and competition may attenuate the relationship between customer base environmental disclosure and supplier emissions. We discuss the contributions to the literature and managerial implications of these findings below.

### 6.1 | Contributions

Our research contributes to the sustainable supply chain management literature in several ways. First, while supply chain decarbonization has received growing attention in the literature (e.g., Gopalakrishnan et al., 2021), most research has focused on supply chain environmental disclosure rather than actual emissions reduction (Jira & Toffel, 2013; Villena & Dhanorkar, 2020). In practice, customers have been struggling to engage suppliers to reduce emissions to tackle climate change (World Economic Forum, 2021), and strategies and solutions to incentivize suppliers' emissions reduction remain less understood, particularly in empirical research. Leveraging signaling theory, we contribute to the literature by identifying the enabling role of customer base environmental disclosure in supply chain decarbonization, which signals customers' environmental commitment. Although environmental

disclosure likely does not immediately result in the realization of carbon neutrality, environmental disclosure is a clear signal of a firm's willingness for its environmental performance to be scrutinized by external stakeholders. From a supplier's perspective, a higher level of customer base environmental disclosure indicates a broad shift in attitudes and norms by customers regarding environmental management, and hence the supplier would be less likely to take the signal as idiosyncratic (Jira & Toffel, 2013). This should motivate the supplier to react and reduce GHG emissions to minimize potential financial and reputational losses (Duan, Hofer, et al., 2021).

The upstream emissions-reducing effect of customer environmental disclosure also advances the environmental disclosure literature. One debate in the environmental disclosure literature is whether voluntary environmental disclosure has a real impact. Some studies suggest that firms strategically use environmental disclosure as greenwashing (e.g., Kim & Lyon, 2011) and outsource their environmental footprint to supply chains under pressures for managing performance and disclosure (Dai, Liang, et al., 2021) while other studies suggest a positive association between disclosure and environmental practice adoption (e.g., Clarkson et al., 2008; Hora & Subramanian, 2019). However, this latter stream tends to focus on internal performance metrics without considering how a firm's disclosure could affect the environmental performance of its supply chain partners. Drawing on signaling theory, our research builds upon the latter stream of literature by illustrating the relationship between customers' environmental disclosure and a supplier's emissions reduction. This finding illustrates an additional benefit of environmental transparency, not only do stakeholders get the intended benefit of being able to monitor the environmental performance of the disclosing firms, the customers in our study, but they also get improved emissions performance of other firms in those customers' supply chains, the suppliers in our study. Thus, our results further increase the importance of environmental disclosures, especially those of firms more downstream in a supply chain, by showing their positive impact on upstream emissions reduction.

Our study also contributes to the literature by exploring boundary conditions that may constrain the beneficial role of customer base environmental disclosure in supplier emissions reduction. Both customer base climate innovation and competition are shown to limit the benefit of customer base disclosure in reducing supplier emissions. Recent literature has called for more research to examine how supply networks shape competitive behaviors (Hofer et al., 2022). Our research complements this literature by illustrating that customer networks, and more specifically, the customer bases, affect a supplier's

competitive behaviors regarding the diffusion of environmental commitment upstream in a supply chain. We find support for the dampening role of customer base competition on the emissions-reducing benefits of customer base environmental disclosure. This finding illustrates that intense competition among customers is related to suppliers having stronger bargaining power, which enables them to resist the pressure of disclosure signals to reduce emissions. Therefore, we contribute to the literature by showing that this customer base structure can determine whether a customer signal can influence supplier environmental performance changes.

Finally, our most surprising finding was the possible attenuating effect of customer base climate innovation because it is in the opposite direction from what was hypothesized. Climate innovations do not emerge overnight but instead come from long-term commitment and expensive R&D investments from environmentally-conscious firms (Lee & Min, 2015). Therefore, we conjectured that customer base climate innovation might serve as a strong and credible signal of the customers' environmental commitment and substitute for that of disclosure in pressing the supplier to reduce emissions. However, we do not find a significant direct effect of customer base climate innovation on supplier GHG emissions. Instead, our extended analyses suggest that suppliers with highly climate-innovative customers may be efficient in environmental performance improvement, possibly because of the stringent supplier selection criteria and supply chain knowledge sharing from these customers, and are therefore less likely to react to the disclosure's signal (Angell & Klassen, 1999; Corbett, 2006; Corbett & Kirsch, 2001; Wilhelm & Villena, 2021). This finding provides an important boundary condition for the signaling effect. Overall, examining these customer-base related boundary conditions is important to evaluate the effectiveness of customer environmental disclosure as a strategy to encourage supply chain decarbonization and eventually for customers to reach supply chain carbon neutrality.

## 6.2 | Managerial implications

Managers are striving to achieve carbon neutrality, not only within their firms but also throughout their supply chains. Our findings have implications for managers, particularly those facing challenges in persuading their suppliers to reduce GHG emissions to achieve decarbonization across the entire supply chain. First, the relationship between a supplier's GHG emissions reduction and the environmental disclosure of its customer base illustrates that a clear and public signal of customers' commitment to reducing environmental impact can have a significant impact on their



suppliers' environmental efforts. Therefore, managers at customers, such as manufacturers, may strategically engage in environmental disclosure to induce suppliers to reduce emissions. The more in-depth the environmental disclosure, the more likely the suppliers are to respond to the signal. Importantly, customers should also be aware that if they are the only customer of a supplier that engages in environmental disclosure, the impact of their disclosure may be weaker. This is because the disclosure of the supplier's entire customer base may play a more critical role in signaling suppliers to take actions towards emissions reduction. Therefore, promoting collective disclosure among customers is crucial, and managers in these companies should be encouraged to collaborate with other companies within and across industries to make environmental disclosure a standard practice.

We also illustrate conditions where customer base environmental disclosures are muted. Managers at customers with high levels of climate innovation should be mindful of the possible attenuation effect when sharing information about their environmental management initiatives with their suppliers. Managers at customers should also be aware of the competition dynamics within their supply chains, specifically when their suppliers also supply many of their competitors. These types of suppliers are more powerful and therefore less affected by the signaling effect of customer base environmental disclosure. For these reasons, managers in customer bases with lower levels of competition or lower levels of climate innovation should be more effective at harnessing the signaling effect of environmental disclosure. In sum, managers may use our research findings to make better decisions regarding managing supply chains to attain carbon neutrality.

Our study also provides implications for policymakers. In the last decade, many countries have enacted a variety of environmental disclosure mandates (Carrots & Sticks, 2020), and some more stringent measures are also under consideration. For example, the U.S. Securities and Exchange Commission has proposed rules on disclosing climate-related information to investors (Gensler, 2022). However, there is an ongoing debate about these mandatory policies focusing on their scope, effectiveness, and negative influence on firm competitiveness (Aragón-Correa et al., 2020; Seiger et al., 2022). Our findings suggest that these mandates may have a positive impact on supply chains as suppliers may reduce emissions to respond to increased customer base environmental disclosure. We also show the characteristics of the customer base where collective customer disclosure is more influential in leading to supplier emissions reduction. This information can help policymakers develop effective environmental policies

based on industry characteristics of innovation and competition. For example, disclosure mandate policies or voluntary programs may be more effective when targeted at industries where firms are less likely to share suppliers (e.g., furniture) and invest less in climate innovations (e.g., lumber and wood products).

### 6.3 | Limitation and future research

Our research is primarily limited by the data available. Our main data sources, Bloomberg ESG and Compustat, include only public firms. Therefore, the suppliers in our sample are all publicly-traded firms. As publicly-traded firms face more scrutiny than private firms, our supplier sample might be limited to those firms that perform well in emissions reduction and thus disclosure. Although this potential selection bias is not found to affect our results from our Heckman selection model analysis, future studies are encouraged to consider a broader sample that includes private suppliers when data become available and to see if our findings can be generalizable to private suppliers. In addition, in examining the customer base, we assume the role of customers is the same across the customer base due to data limitations. Future research could examine the heterogeneous effects of different customers on a supplier in environmental management. Furthermore, we examine environmental disclosure as one way to show a customer's commitment towards environmental transparency to address climate change, and future studies could examine alternative ways to capture the customer's climate commitment, such as by examining a customer's announcement of climate goals and the associated signaling effects. In particular, customers may make a long-term commitment to collaborate with suppliers in environmental management, and therefore future research, with longer supply chain panel data and granular data on customer-supplier environmental collaboration, could examine the temporal effect of customer-supplier collaboration in supply chain disclosure and decarbonization. Last, our study does not provide direct causal evidence between customer base environmental disclosure and supplier GHG emissions, despite the fact that we have addressed a variety of endogeneity concerns (e.g., self-selection and omitted variables). Future studies can analyze the causality of the relationship by employing randomized controlled trials or identifying an exogenous shock for quasi-experiment.

### ACKNOWLEDGMENTS


The authors thank Suzanne de Treville, the guest editors of the special issue, the associate editor, and the

anonymous reviewers for their constructive feedback on the article.

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## ENDNOTES

<sup>1</sup> Scope 1 emissions are “direct GHG emissions that occur from sources that are owned or controlled by the company,” and Scope 2 emissions capture “GHG emissions from the generation of purchased electricity consumed by the company” (Wbcsd, & W. R. I., 2015, p. 25).

<sup>2</sup> Environmental disclosure formally refers to the breadth of information available regarding a firm’s environmental impacts and practices and is an indication of the firm’s environmental transparency (Bellamy et al., 2020).

<sup>3</sup> The customer base is comprised of the customers that the supplier directly supplies products to akin to how the supply base is comprised of all the first-tier suppliers that the customer directly receives products from (see Choi & Krause, 2006, Dong et al., 2020, and Hu et al., 2022 for further discussion of the supply base).

<sup>4</sup> A point worth noting is that a customer’s environmental disclosure score measures the number of environmental indicators that the customer is disclosing, as opposed to the actual performance on those indicators. In other words, the actual value of the environmental indicators is not used for calculating the environmental score (Bellamy et al., 2020; Eccles et al., 2011; Lopez-de-Silanes et al., 2020). Hence, the environmental disclosure score can be viewed as the reflection of a customer’s level of environmental transparency (Bellamy et al., 2020; Yu et al., 2018), which is relevant in our setting to study signaling effects.

<sup>5</sup> Note that an individual supplier’s emissions performance is not an indicator for Bloomberg to calculate a customer’s environmental disclosure score. For more details, please see Table A6 of Bellamy et al. (2020) for a list of environmental indicators used by Bloomberg in calculating environmental disclosure scores.

<sup>6</sup> In our sample, the average supplier GHG emissions is  $\frac{4122}{1000}$  thousand metric tons. Hence,  $\Delta = \text{emissions}^S \times (e^{\beta_1 \times \sigma} - 1) = 4122 \times (e^{-0.003 \times 13.51} - 1) = -163.7$ .

<sup>7</sup> Note that this measure would be zero if there is only one customer in a supplier’s customer base.

<sup>8</sup> We thank the review team for their constructive feedback and suggestions for this section.

<sup>9</sup> We use PSM with calipers of width equal to 0.1 of the standard deviation of the propensity score and without replacement (Fan et al., 2022).

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

**How to cite this article:** Song, S., Lian, J., Skowronski, K., & Yan, T. (2024). Customer base environmental disclosure and supplier greenhouse gas emissions: A signaling theory perspective. *Journal of Operations Management*, 70(3), 355–380. <https://doi.org/10.1002/joom.1272>