Green links: Corporate networks and environmental performance

Hossein Asgharian,[1] Michał Dzieliński,[2] Zahra Hashemzadeh,[3] and Lu Liu[4]

Abstract

We investigate how corporate environmental performance propagates in firm networks. We find that the degree of spillover depends on the type of link between firms as well as their relative strength in the network. In terms of link type, the effect is strongest among competitors, especially in industries that are highly concentrated, consumer-facing and for which environmental risks are material. Stronger firms, as measured by market share and total number of links, affect their competitors more, while being less affected themselves. We also find that firms in highly concentrated industries and those with weak network position are affected by their customers and suppliers. Importantly, we find that network propagation results in improvements of environmental performance - the effect on the focal firm is stronger when the related firm improves its environmental score and if the focal firm's own score is low. Finally, changes in aggregate environmental performance entail changes in both declared policies and real activities, such as CO_2 emissions. Overall, network effects are a significant force shaping firms' environmental performance, and a force mostly for good.

Keywords: Sustainability, ESG, Environmental Performance, Corporate Network, Corporate Social Responsibility

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[1] Hossein Asgharian: Department of Economics, Lund University, Box 7082, 22007 Lund, Sweden. Email: Hossein.Asgharian@nek.lu.se.

[2] Michał Dzieliński: Stockholm Business School, Stockholm University, 10691 Stockholm, Sweden. michal.dzielinski@sbs.su.se.

[3] Zahra Hashemzadeh: Department of Economics, Lund University, Box 7082, 22007 Lund, Sweden. Email: zahra.hashemzadeh@nek.lu.se.

[4] Lu Liu: Stockholm Business School, Stockholm University, 10691 Stockholm, Sweden. Email: Lu.Liu@sbs.su.se.

1. Introduction

Climate change is an existential challenge to humanity. According to current estimates, we must address this challenge in the next 20–30 years, yet urgent action is hampered by its complex and global nature. No single country or group of countries can enforce environmental standards on companies in other countries, but each is very much affected by the greenhouse-gas emissions and other forms of pollution these foreign companies generate. Multinational cooperation through, for example, the United Nations can pave the way forward, but it tends to be slow and subject to political shifts. It is also largely focused on high-level targets rather than company-level improvements.

Such frictions lend importance to a different channel for spreading environmental policies and actions around the globe—corporate networks. Relationships in those networks can take different forms, such as between competitors, customers, and suppliers, or partnerships focused on, for example, joint research or operational activities. Companies connected through such networks affect each other, enabling the transmission of, for example, engagement in innovation and R&D (Chu et al., 2019), knowledge and information (Cen et al., 2019), capital structure (Leary and Robert, 2014; Chu and Wang, 2017; Oliveira et al., 2017), trade credit (Zhang et al., 2020), and tax avoidance (Cen et al., 2017).

Environmental issues play an increasingly important role for corporations, both in terms of public attention and regulation stringency. Implementation of environmentally friendly policies may create a competitive advantage for the firm as it may attract customers from other firms producing the same product, which in turn may force these other firms to also implement such policies. Furthermore, companies are exposed to the risk created by their customers, suppliers, and partners.

They are therefore concerned not just about their own but also their network's environmental performance. In this paper, we analyze corporate networks as a global conduit for environmental policies and actions. Using comprehensive data on linkages among companies worldwide, we investigate how the environmental performance of a firm is affected by the environmental performance of its related firms. To measure environmental performance, we use the environmental pillar score (*EnvScr*) from Asset4, a leading provider of environmental, social, and governance (ESG) ratings. We find that related firms' *EnvScr* significantly predicts the focal firm's *EnvScr* one year later. This is consistent with research showing a significant effect from customers' environmental and social performance on that of their suppliers (Schiller, 2018). In the cross-section, we find that the effect on focal firms with greater market shares and more links, a measure of network centrality, is weaker. These firms have a stronger position in the product market with less substitutability and consequently greater bargaining power. As a result, they are expected to be the driving force of the environmental policies and less sensitive to the policies taken by firms in weaker positions. Interestingly, the market-share and centrality effects are largely independent of each other, they remain significant when examined jointly.

Secondly, we investigate the role of specific types of links: competitors, customers, suppliers, as well as partners, which includes firm relations, such as research and operational partnerships. Thus, our contribution is to compare the transmission of environmental performance across different types of corporate links. To the best of our knowledge, we are the first to undertake such a comprehensive examination,[5] which we believe is crucial to understanding which channels work best to bring about much-needed improvement in companies' environmental performance. We find

[5] Other papers have looked at a single link type in isolation, such as between customers and suppliers (see, e.g., Schiller, 2018).

that peer pressure from competitors is the most significant channel of environmental transmission. However, focal firms with few links are also significantly affected by their customers, suppliers and partners. Importantly, we find that network propagation results in environmental-performance improvements - the effect on the focal firm is stronger when the related firm improves its environmental score and if the focal firm's own score is low.

In addition, we consider industry-level factors that could moderate the transmission of environmental performance: the degree of competition in the industry, the environmental materiality of the industry to which the firms belong, and if firms belong to consumer-facing industries. In a highly concentrated industry, few firms compete for market share and changes in a single firm's demand, due to changes in its environmental policy, can substantially affect the market shares of other firms in that industry. Moreover, firms in a highly concentrated industry are more subject to scrutiny, which may force them to enhance their environmental impacts if rivals do so. Therefore, after controlling for firm size, we expect a larger spillover of environmental policy in highly concentrated industries and that the firms in highly concentrated industries are more sensitive to pressures from their competitors, customers, suppliers, and partners. Furthermore, we expect the spillover to be greater in industries where environmental issues are of high relevance to firms' financial performance. We use the industry-level materiality map from the Sustainability Accounting Standards Board (SASB) to capture this. Finally, we use a demand-oriented industry classification to investigate if the transmission of environmental policies is stronger when focal firms belong to consumer-facing industries, as this group may face widespread public pressure on environmental issues.

We find that high industry concentration increases the transmission effect along all types of links, including the supply chain and other partnerships. Similarly, the environmental-performance

transmission is stronger among firms for which the environment is a financially material issue. We also find that the transmission effect among competitors is stronger in consumer-facing industries.

In our final analysis, we investigate how network transmission affects specific aspects of aggregate environmental performance. In particular, we compare the transmission of a more "declarative" aspect—adopting a policy to reduce greenhouse gas emissions—and real outcomes—changes in actual CO2 emissions. For competitors, we find a significant effect on both aspects. Thus, transmission affects not just words, but also deeds. This helps alleviate concerns that *EnvScr* may be inflated due to "greenwashing,"

Our results suggest that to maximize the "ripple effects" of environmental performance across the corporate network, regulators, activists, and other interested stakeholders (i.e., customers, suppliers and other partners) should focus on highly central firms with large market share in highly concentrated industries, for which the environment is a financially material issue. Focusing their energy on the most promising targets is key, given limited time and resources to bring about much-needed environmental-performance improvements. Our results should also encourage managers of such firms to take the lead in improving environmental performance, knowing that their actions will spread through their companies' networks and generate positive externalities. The upshot is that network transmission acts to improve firms' environmental performance, both in terms of adopting pro-environment policies and improving real outcomes, such as reducing CO_2 emissions.

Our work sits at the crossroads of emerging literature on sustainable finance and transmission in corporate networks. First, considerable research documents the propagation of corporate policies and information between customers and suppliers. Barrot and Sauvagnat (2016) show that firm-level idiosyncratic shocks caused by local natural disasters propagate from suppliers to customers and leads to output loss. Cohen and Frazzini (2008) find that stock prices do not promptly

incorporate news about supply-chain partners and that return predictability exists across customers and suppliers. Hertzel et al. (2008) document that customer–supplier relationships transmit customers' financial distress and bankruptcy risk to their suppliers and engender a negative and significant effect on suppliers' stock price. Chu et al. (2019) show customers' positive causal effect on supplier's innovation output for pairs with geographical proximity.

Second, a growing literature studies transmission of corporate decisions among industry peers. Among others, Leary and Roberts (2014) find that firms' financing decisions respond to those of peer firms. Aghamolla and Thakor (2021) show that a firm's IPO decision affects those of its competitors. Moreover, the literature shows spillover effects through other types of corporate networks. For example, Boone and Ivanov (2012) find bankruptcy spillover within collaborative partnerships in strategic alliances and joint ventures. Cao et al. (2016) find evidence of stock-return predictability across alliance partners.

One underexamined research question in the literature of corporate network spillover is whether the adoption of sustainability-friendly practice propagates to economically linked firms. Cao et al. (2019) study the propagation of firms' corporate social responsibility (CSR) adoption within U.S. firms' rival networks. They use a regression-discontinuity approach based on the passage or defeat of CSR proposals in shareholder meetings and document an adoption of similar practice by peer firms as a strategic response to competitive threat. Our study is closely related to Schiller (2018) who documents that corporate customers have a statistically significant and economically meaningful effect on suppliers' environmental (E) and social (S) policy choices and performance. The direction of propagation is from customers to suppliers especially when customers have greater bargaining power and suppliers are in countries with lower ESG standards (Shiller, 2018).

Our paper also complements the strand of literature seeking to explain why corporations undertake sustainability measures despite the underlying cost. Based on the neoclassical economic judgement, firms' focus on ESG-related performance leads to a "wrong" corporate objective function. That is, firms should focus on profits or shareholder wealth rather than social responsibility (Friedman, 2007; Reich, 2008; Karnani, 2010). Therefore, firm's engagement in sustainability action must be motivated. Studies document different incentives for firms' participation in such activities: such as relaxed financial constraints,[6] shareholder engagement and active ownership (Akey and Appel, 2019; Dimson et al., 2021; Naaraayanan et al., 2020), managerial agency problems,[7] avoiding reputational risks (Hong et al., 2019), and strategic implications such as competitive advantage (Baron, 2001; McWilliams et al., 2006). In this paper, we investigate a new, relatively underexamined channel: corporate-network transmission.

The rest of the paper is organized as follows. In Section 2, we describe the data and regression model. In Section 3 we present our main results. Section 4 concludes.

2. Data and Model

We first present the data and describe and motivate the variables used in the analysis (Section 2.1). We then discuss our empirical model (Section 2.2).

2.1 Data

We combine three kinds of data in our analysis: corporate relationships from FactSet Revere, ESG performance from Asset4, and accounting data from Eikon. Our unit of observation is the firm-

[6] A constrained firm's sustainability score increases more with its idiosyncratic equity valuation and lower cost of capital comparing to a less-constrained counterpart (Hong et al., 2012).

[7] Corporate managers engage in these activities in order to enhance their own utility rather than the welfare of shareholders (Bénabou and Tirole, 2010; Bertrand and Mullainathan, 2003; Cronqvist et al., 2009; Cheng et al., 2013).

pair–year: two firms connected through one of the types of relationships defined below in a given year. We identify 302,437 firm-pair–years over the period from 2004 to 2019, where we also have the required ESG and accounting data for both firms involved, representing 106,845 unique pairs and 2,842 firms worldwide, a substantially larger sample compared to previous research covering, most importantly, the full spectrum of economically meaningful corporate relationships.

FactSet Revere covers over 10,000 companies involved in over 155,000 relationships, including both direct (named by company) and reverse (named by other companies) relationships, retrieved from such sources as SEC 10-K annual filings, investor presentations, and press releases. Each relationship is assigned to one of the categories, summarized in Table 1. Based on this information, for each related firm *r*, we define its relationship to the focal firm *f* as

i) Competitor: company *r* is a competitor of focal company *f* if either of the companies reports the other firm as its competitor in FactSet.

ii) Customer: company *r* is a customer of the focal company *f* if company *f* reports company *r* as its customer or company *r* reports company *f* as its supplier.

iii) Supplier: company *r* is a supplier of the focal company *f* if company *f* reports company *r* as its supplier or company *r* reports company *f* as its customer.

iv) Partner: company *r* is a partner of focal company *f* if either of the companies reports the other company as a partner of at least one of the subcategories under partnership shown in Table 1. We aggregate all the subcategories into partnership as the number of links in each subcategory is small compared to the other categories defined above. Since, firms may be related with more than of the subcategories, the number of unique partners in the table is less than the sum of the numbers in the subcategories.

Asset4 is one of the premier providers of ESG data, covering more than 10,000 companies worldwide. The database contains 186 individual metrics, which are aggregated into 10 Category scores, three Pillar scores and finally an overall ESG score, according to a weighting formula described in Refinitiv (2020). The scores are adjusted to be comparable across different industries. We focus on *EnvScr*, which combines three Category scores: Emissions, Resource Use, and Innovation, which are in turn based on a total of 68 metrics. Thus, we believe the *EnvScr* broadly captures a firm's environmental performance in its operations.

The transmission of environmental performance among the firms may depend on characteristics of companies, as well as the industries in which they operate, and we explore this heterogeneity later in the analysis. We hypothesize that strong firms should be the drivers of environment-related innovations and policies, and less sensitive to policies implemented by other companies. We use two proxies for a firm's strength: market share, which captures a firm's competitiveness, and network centrality scores, which capture a firm's importance and connectedness in different types of networks. Next, we hypothesize that the firms in highly concentrated industries are more sensitive to pressures from their competitors, customers, suppliers, and partners, so we use the Herfindahl–Hirschman index (HHI) to measure industry concentration. Further, we hypothesize that transmission will be stronger among firms for which environmental issues are "material"—that is likely to impact their operational and financial performance.[8] We use the SASB industry-level materiality map to identify such companies. Finally, we use the demand-oriented industry classification, Global Industry Classification Standard (GICS), to investigate if the transmission

[8] SASB defines financial materiality as: "information is financially material if omitting, misstating, or obscuring it could reasonably be expected to influence investment or lending decisions that users make on the basis of their assessments of short-, medium-, and long-term financial performance and enterprise value." (https://www.sasb.org/wp-content/uploads/2020/08/Invitation-to-Comment-SASB-CF-RoP.pdf)

of environmental policies is stronger when focal firms belong to consumer-facing industries compared to the case in which firms' customers are mainly other firms.[9]

Details of the variable construction are presented below.

- Market share (*MktShr*) is calculated as the ratio of the firm's total sales to the sum of the total sales of the firms competing in the same market as the focal company, based on the definition of competitor firms above.
- Centrality is calculated in two ways:
    - Number of links (*NumLks*) of focal firm *f* is defined as the total number of firms linked to that firm via at least one of the relationships (ii)–(iv) defined in Section 2.1. Note that even if two firms are related through more than one relationship (e.g., firm *r* is both a customer and partner of firm *f*), we count that as one link between the two. Thus, the network we consider is unweighted.
    - Supply-chain Kleinberg centrality (*KCntrl*) measures the relative importance of a firm as a customer or supplier in the supply-chain network. Kleinberg (1999) proposes two types of centrality: authority centrality and hub centrality for directed networks. In the supply-chain network, authorities correspond to important suppliers and hubs correspond to important customers. High supplier centrality indicates that the firm is a supplier of many customers with high customer centrality, while a high customer centrality implies that the firm is the customer of many suppliers with high supplier centrality. The customer and supplier Kleinberg centralities capture firms' relative bargaining power and their ability to switch to

[9] The GICS has 11 sector classifications: Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Health Care, Financials, Information Technology, Communication Services, Utilities, and Real Estate. The GICS is developed by MSCI.

other supply-chain partners. The Kleinberg centralities are measured using the largest eigenvalue of the products of the customer and supplier network matrices (see also Wu, 2015). More formally, denote the supply-chain matrix at a given point in time by the square adjacency matrix $\boldsymbol{A}$**,** where the element $A_{i,j}$ of the matrix is one if the company in column j is the customer of company in row i and zero otherwise. The eigenvalue decomposition of the product $\boldsymbol{A}'\boldsymbol{A}$ is

$$\boldsymbol{A}'\boldsymbol{A}\boldsymbol{c} = \lambda\boldsymbol{c},$$

where $\boldsymbol{\lambda}$ is the matrix of eigenvalues and $\boldsymbol{c}$ gives the corresponding eigenvectors. The column of $\boldsymbol{c}$ that corresponds to the largest eigenvalue of the product matrix defines the vector of customer centrality of the firms in the sample. The supplier centrality is defined similarly using the product $\boldsymbol{A}\boldsymbol{A}'$ in the equation above.

- HHI is calculated using each firm's market share.

$$HHI = \sum_{i=1}^{N} \mathrm{MktShr}_i^2$$

- Materiality is defined based on SASB's assessment of the sustainability factors that are material to short-, medium-, and long-term enterprise value in a given industry. We use SASB's proprietary Sustainable Industry Classification System (SICS), designed to group companies based on shared sustainability risks and opportunities, and focus on the six factors of the Environment dimension: GHG Emissions, Air Quality, Energy Management, Water & Wastewater Management, Waste & Hazardous Materials Management, and Ecological Impacts. We consider Environment to be material for companies in a given industry if at least two of the six factors are rated as material by SASB.

To isolate the effect of transmission from related firms to the focal firm, we need to control for the variation of environmental score caused by the focal firm's own characteristics. We follow prior empirical research in selecting firm-specific characteristics that may explain environmental-performance variations. More specifically, we use the following control variables to account for focal firms' characteristics that may affect their E-score.

- Firm size: Larger firms face greater political and social attention and their environment actions may be subject to a higher degree of scrutiny, compared to smaller firms. In addition, larger firms should be better equipped to utilize economies of scale to implement new technologies (see, e.g., Artiacha et al., 2010). Therefore, following existing literature (Dai et al., 2021; Schiller, 2018), we control for size measured by the logarithm of total assets.
- Leverage: Highly leveraged firms may face limitations for financing new technology required to enhance environmental performance. Therefore, we expect a negative impact of high leverage on companies'*EnvScr*. We may also expect a reverse causal relationship between these variables, as poor environmental performances may increase the uncertainty of firms' future cash flow and thus negatively affect firms' borrowing capacity and lower their leverage ratio. Following earlier literature (see, e.g., Ferrell et al., 2016; Dai et al., 2021; Schiller, 2018), we control for leverage ratio measured as the ratio of total debt to the book value of their total assets.
- Research and development (*R&D*): Investment in R&D improves firms' abilities to shift from traditional high-pollution production practices to modern and sustainable ones. A number of empirical studies find a positive effect of R&D investment on firms' CSR and their environmental performance (see, e.g., Alam et al., 2019; Padgett and Galan, 2010;

Chakrabarty and Wang, 2012). We use the ratio of R&D expenses to total sales to control for firms' intended technological advancements.

- Market-to-book ratio (Tobin's *q*): Tobin's *q* measures companies' future growth opportunities. It is also considered as a proxy for management's ability to generate value from a unit of underlying assets (see, e.g., Buchanan et al., 2018). We therefore expect a positive effect of Tobin's *q* on environmental performance. However, as with leverage, we may face reverse causality because firms' sustainability performance may affect their market valuation through different channels (see, e.g., Buchanan et al., 2018). For example, sustainability performance is expected to reduce regulatory and legal risk and earn stakeholders' trust. Thus, we follow Schiller (2018) and control for Tobin's *q*.
- Profitability: Profitable companies satisfy shareholders' financial expectations and have required funds to improve their social and environmental impacts, while companies with low profit need to reduce their costs to be able to provide returns to their investors (see, e.g., Artiacha et al., 2010). Therefore, we expect a positive effect from profit on companies' *EnvScr*. Similar to most of the variables discussed above, firms' sustainability policy may affect their future profitability. On the one hand, penetrating new business segments, including sustainable products, will entail considerable costs and risks. Also, the company may create value through the accumulation of social capital, which can strengthen its brand, increase its market share, and increase sales and profitability (see, e.g., Lins et al., 2017). We control for firm profitability using return on assets (*ROA*).

Table 2 presents the descriptive statistics of the variables used in the regression model. We drop observations with negative equity values and winsorize value of Tobin's *q* to 1% from above, and *R&D* and *ROA* to 1% from both sides. Environmental scores range between 0 (worst) and 100

(best) and have a slightly left-skewed distribution. It should be noted that skewness and kurtosis of all the variables are significantly different from normal, which is partly due to the large number of observations (302,437).

2.2 Empirical Model

We estimate the following panel-data regression model

$$EnvScr_{f,t} = \alpha_{fr} + \delta_t + \beta\ EnvScr_{r,t-1} + \sum_{k=1}^{K} \gamma_k X_{k,t-1} + \varepsilon_{f,t}, \quad (1)$$

$$f = 1, \dots, N \text{ and } r = 1, \dots, M,$$

where $EnvScr_{f,t}$ and $EnvScr_{r,t}$ are the environmental scores of the focal firm *f* and related firm *r*, respectively, at time *t*, $X_{k,t}$ is the value of control variable *k* at time *t*, α_{fr} is the pair fixed-effect parameter, and δ_t is the time fixed-effect parameter. Also, as most of the control variables may have a two-sided causal relationship with sustainability performance, we follow earlier literature in this field (see, e.g., Shiller, 2018) and use one-year lagged values of all the control variables. We use firm-pair fixed effects instead of (focal) firm fixed effects to capture time-invariant characteristics that affect firm-, industry-, and country-pair levels of environmental performance. β is the parameter of interest and shows the effect of the related firm's *EnvScr* at time *t*−1 on the focal firm's *EnvScr* at time *t*, and γ_k is the parameter for the control variable *k*. $\varepsilon_{f,t}$ is the residual term of the regression for focal firm *f* at time *t*. *N* and *M* are the numbers of focal firms and related firms, respectively, used in the estimation. Because we use different relationships to estimate the model, *N* and *M* can vary by the type of the relationship under consideration.

To investigate how the transmission of environmental performance among firms depends on their relative competitiveness in the product market or their position in different economic networks,

we augment the model in Equation (1) by interacting the related firm's *EnvScr* with market shares and centrality scores of both the related firm itself and of the focal firm.

$$EnvScr_{f,t} = \alpha_{fr} + \delta_t + \beta\, EnvScr_{r,t-1} + \sum_{l=1}^{L} \theta_l Z_{lt-1} EnvScr_{r,t-1} + \sum_{l=1}^{L} \varphi_l Z_{lt-1} + \sum_{k=1}^{K} \gamma_k X_{k,t-1} + \varepsilon_{f,t}, \tag{2}$$

The $L \times 1$ vector of interaction variables $\boldsymbol{Z}_t$ includes four variables:

$$\boldsymbol{Z}_t = \left[MarketShare_f, Centrality_f, MarketShare_r, Centrality_r\right]',$$

where, $MarketShare_f$ and $Centrality_f$ stand for market share and centrality score of the focal firm *f*, and $MarketShare_r$ and $Centrality_r$ denote the corresponding variables for the related firm *r*. Since firms with better environmental performance may gain market share and attract new customers and suppliers, we may have a reverse causality between these interaction variables and firms' environmental scores. We therefore use the lagged values of these variables in the regression.

3. Results and Analysis

In this section, we present and analyze the estimation results. Section 3.1 presents our baseline analysis investigating the transmission of environmental performance among related firms without separating the different types of relationship. The aim is to provide an overall view of the importance of firms' network connections for environmental-performance spillover and to analyze the robustness of model selection. In Section 3.2, we investigate the importance of different types of the relationships for environmental-performance transmission and analyze to what degree firms' relative market power and their placement in the network affect environmental-performance

spillover. Section 3.3 demonstrates how the transmission depends on the level and the direction of environmental-performance changes. In Section 3.4. we analyse if industry characteristics, such as concentration and the degree of environmental materiality, matter for the degree of environmental-performance transmission. Finally, in Section 3.5, we replace the overall environmental scores with two specific measures, CO_2 emissions to represent real outcomes and firms' policies for reducing emissions to capture declarative outcomes.

3.1 Baseline Analysis

We start our analysis by considering the transmission of environmental performance, captured by each company's *EnvScr*, between firms that are related to each other through at least one of 16 relationship forms reported in the FactSet database. The purpose of this part of the analysis is to give an initial view of whether firm links contribute to environmental-performance transmission.

Table 3 shows the results of the pair fixed-effect estimation of the regression model with the focal companies' *EnvScr* as the dependent variable and the one-year-lagged *EnvScr* of companies with any form of relationship to the focal company as our main independent variable of interest. We also include lagged values of five control variables to account for company-specific characteristics that can affect the *EnvScr* of the focal companies. In all the reported estimations, we use year dummies to capture *EnvScr* variations over time.

The first column of Table 3 shows that the *EnvScr* of the related firms is positive and highly significant, which indicates spillover of environmental performance among related firms. In terms of economic magnitude, an increase in a related company's *EnvScr* by one standard deviation implies an increase in the *EnvScr* of the focal company by 1.2% of a standard deviation. The coefficients of all the control variables, except that of Tobin's *q*, are significant. The signs of the coefficients are in line with the expectations and show that large, profitable firms and firms with

low leverage and high R&D expenses have higher *EnvScr*, as found by Dyck et al. (2019). The value of within R^2 indicates that around 2% of all the cross-sectional and intertemporal variations in companies' *EnvScr*s can be explained by the model. Comparing this value with the model's total R^2 (94%) shows that much of the cross-sectional and intertemporal *EnvScr* variations are due to pairwise and time fixed effects.

To analyze how each firm's own relative market power affects environmental-performance spillover from related firms, we add the interaction of the related firm's *EnvScr* with the focal firm's and related firm's market shares. Similarly, we include the interaction with their total number of supply-chain and partner links to account for relative bargaining power of the pair, which may affect the focal firm's sensitivity. Columns (2)–(4) of Table 3 presents the results. We first estimate the model including market share and number of links individually, Columns (2) and (3), and then together, Column (4). The results remain robust. The coefficients of the interaction terms of the focal firms' variables are both negative and highly significant, indicating that firms with larger market share and more stakeholder firms have stronger positions and are less likely to follow related firms' environmental performance, ceteris paribus. The coefficients of the interaction terms of the *EnvScr* with market share and the related firms' number of links are both positive as expected, but only the latter is significant. We may conclude that the environmental-performance spillover from related firms to focal firms significantly depends on the relative strength of the focal firm in the product market and economic network. Since companies' *EnvScr*s do not vary substantially over time, we also estimate the model by including the lagged values of

focal firms' *EnvScr*. The last column of Table 3 shows the results of this estimation. The coefficients of interest all remain robust to inclusion of the lagged *EnvScr*.[10]

3.2 Effect from Different Relationships

Next, we dig deeper and compare the relative importance of different economic networks for transmission of companies' environmental actions. To this end, we group the 16 forms of relationships into four categories: competitor, customer, supplier and partner, a group that includes partnerships other than those related to the supply chain (see Table 1 for details). Table 4 gives the estimation results for the model when transmission from related firms belonging to each of the four categories (competitors, customers, suppliers, and partners) is considered separately. The coefficient of the *EnvScr* of the related firm is positive and highly significant only when focusing on competitors as related firms. Note that the environmental scores are industry adjusted and pairwise fixed effects should capture the differences in the level of the scores across firms. Therefore, the stronger result obtained for competitors is not because of groupwise similarities of firms' *EnvScr* within the same industry. The last rows of Table 4 show that the coefficients of the control variables are, with some exceptions, qualitatively the same, suggesting similar conclusions across different categories of connections. The result above shows that on average, transmission of environmental performance is strongest among competitors. This does not mean that in other categories, certain firms, such as more connected ones, could not have a significant transmission effect—an issue we address next.

To investigate if firms with large market share or many connections in different networks are the drivers of environmental performance, similar to Column (4) of Table 3, we extend the model with interaction terms between the *EnvScr* of the related firms with the market share and number of

[10] In addition, we estimate the model with Breitung et al., (2021) bias-corrected approach. The results remain robust.

linked stakeholders of the focal and related firms. The first column of Table 5 illustrates the result of the estimation for competitors. The coefficient on *EnvScr* is positive and significant, showing a significant environmental-performance spillover between competitors. The interaction parameters, except that of the market share of the focal firm, are all significant with signs that support our expectation. Specifically, the *EnvScr* spillover weakens with the strength of the focal firm, in terms of its number of connections in different networks, and it becomes stronger as the related (competitor) firms' market power and number of connections increase. Furthermore, the coefficient on *NumLks-F* is positive and significant, showing that, after accounting for other characteristics and the competitor spillover effect, more-connected focal firms have better environmental performance.

The second column of Table 5 presents the coefficients of the augmented model for the effect from customers, with suppliers as focal firms. We find a positive impact of consumers' environmental score for suppliers and, similar to the case of competitors, the effect is increasing (decreasing) with the strength of related (focal) firm. All the interaction variables, except that of the customers' market share, are significant. Column (3) of Table (5) shows a spillover from suppliers' *EnvScr* on that of customers. The coefficients of the interaction term with the focal (customers) and related firms' (suppliers) number of links are significant with the expected signs. The interaction term with the related firms' market shares has a negative sign which is unexpected but also only marginally significant at the 10% level.

The last column of Table 5 shows the estimated coefficients for partner companies, related through joint operational and financial activities. The interaction terms are significant for focal firms' market share and number of links, indicating that firms with strong position in the output market and those with large number of links are in general less sensitive to their partner firms' policies.

The coefficient of *EnvScr-R* is significant for all four relationships in Table 5 but only for competitors in Table 4. The former coefficient shows the effect of *EnvScr-R* when the interaction variables (*MktShr* and *NumLks*) are all zero, see Equation (3), whereas the latter does not consider the interaction variables. This difference can be attributed to inclusion of the interaction terms.

We also find that the coefficients of the market share of the related firms are significant for both supplier and customer effects. This suggests that firms with large suppliers and customers need to improve their environmental score as their actions might be indirectly subject to scrutiny by the market. Analogously, we expect that the coefficients of the focal firms' market share, *MktShr-F,* should be positive and significant. This is only the case in the regression for effects from partners. The insignificance of this coefficient in Columns (1) to (3) of Table 5 may be because the variable *Size*, which is highly significant in all regressions, captures the effect of focal firms' market share.

To illustrate in more detail how relative market power of focal and related firms affects the spillover of environmental performance, we compute the marginal effect of the related firms' *EnvScr* on focal firms' *EnvScr*, as a function of the interaction variables in Table 5. Formally, the marginal effect is given by

$$\frac{\partial E\text{-}score_f}{\partial E\text{-}score_r} = \beta + \sum_{l=1}^{L} \varphi_l Z_{lt}, \tag{3}$$

Z = MktShr-F, NumLks-F, MktShr-R, or *NumLks-R*

We calculate the marginal effect of each of the four interaction variables by fixing the other three interaction variables at their mean values while changing the value of the variable under consideration. Figure 1 illustrates the results. We only show the results for interaction terms that are significant at least at the 5% level. For all four categories of relationships, an increase in the

focal firm's number of links, *NumLks-F*, considerably decreases their sensitivity to the related companies. In some cases, the effect for focal firms with a large number of links becomes even negative and significant, which seems to be counterintuitive. This negative marginal effect might be due to the linearization of a likely nonlinear relationship. We have a similar but weaker effect for the focal firm's market share, *MktShr-F*, for the customer and partner effects. Looking at the interaction variables of the related firms, we observe a considerable impact from both the competitors' market share and number of links on the marginal effect. The marginal effect also increases with focal firms' customers' and suppliers' increasing number of links, but it only becomes significant for the latter case. In general, we may conclude that well-connected firms drive environmental performance in the product market and those with few links generally follow.[11]

Now, we focus specifically on the supply chain and investigate if the supply-chain transmission of environmental performance depends on firms' positions, namely their centrality as customers and suppliers in this network. To this end, we estimate the same model as in Table 5 but replace the number of links with Kleinberg centrality in the supply-chain network (Table 6). More specifically, if we consider the model that investigates the effect from customers on suppliers, we use the supplier centrality for focal firms and customer centrality for related firms. Conversely, for the effect from suppliers to customers, we use customer centrality for focal firms and supplier centrality for related firms.

[11] Firms with many links are normally the large firms. To investigate if the significance of the number of links is mostly the network effect rather than the size effect, we run the regressions in Table 5 by replacing focal and related firms' market shares with firm size. The results remain robust, as for all the relationships the interaction terms with the focal and related firms' number of links remain significant even after inclusion of *size*. The results for the interaction terms of the firm size are mainly similar to those obtained for market share in Table 5.

The estimates of the effect from suppliers are, in general, similar to those in Table 5, showing that the effect from suppliers increases with supplier centrality and decreases with customer centrality. However, the model for the effect from customers does not show any significant result for the interaction terms of the centrality measures. To see if the weaker results for the customer regression depends on how we estimate the centrality measure, we run the same regression replacing the centrality measures with the number of suppliers (customers) for each customer (supplier) firm; see Columns (3) and (4) of Table 6. The results remain almost the same, which shows that the weaker results of the customer regression in Table 6 are mostly due to the type of related firms rather than how we measure the centrality. The fact that firm centrality in the supply-chain network plays a weaker role than that in the network with all related firms points to the need to undertake a comprehensive examination of various types of links. When examining the spillover effect from customers and suppliers, it is important to consider not just firms' centrality as customers and suppliers, but also their connections with other types of related firms.

3.3 Leaders Pulling Up or Laggards Dragging Down?

In this Section, we investigate if the spillover depends on the level and the direction of the changes in environmental performance. This is an important dimension, because what is needed for a successful transition to sustainability is for improvements in environmental performance to spill over in the corporate network. However, the transmission effect we identified previously could, in principle, be symmetric, that is related firms with bad and worsening environmental could be also dragging down the focal firms.

We start by dividing the sample based on the median value of the focal firms' lagged environmental scores, into two groups, *Low* and *High*. We expect the effect from the environmental scores of the related firms to be larger if the focal firm has a low score, since the

focal firms do not feel pressure to improve their environmental performance if they already perform well. The results are reported in Columns (1) and (2) of Table 7 for all the four types of relationship. They support our conjecture and show that the spillover among competitors is only significant for focal firms with low initial environmental scores. The coefficients of the lagged environmental scores of customers and suppliers are also positive and significant at 10% level for supplier and partner effects only when the focal firm has low initial environmental scores.

Further, we expect that firms adjust their environmental performance to that of the related firms, only if the related firms improve their environmental performance. Therefore, we divide each of the low and high samples in two groups based on the sign of related firms' changes in environmental performance, those that have a negative change (decrease) and those with a positive change (increase). The results in Columns (3) to (6) of Table 7 again support our expectation and show that focal firms improve their environmental performance only when they have poor performance, and their competitors take on positive environmental actions. The size of the coefficient (0.0343) is about 50% larger than the average effect among competitors (0.0244, see Table 4). We do not observe significant coefficients for the other three relationship types, but the magnitude of the effect is much larger for all the relationships when the focal firm has a low score and the related firms increase theirs.

3.4 The Role of Industry Characteristics

In this Section, we focus on such industry characteristics as concentration, degree of environmental materiality, and customer type. The HHI captures the overall level of concentration or competition in the product market. To analyze if the spillover effect depends on the degree of competition, we divide the sample based on the focal firm's industry HHI. Firms in industries with above-median HHI are assigned to the *High* group and the rest to the *Low* group. Columns (1) and (2) of Table 8

show the results. The spillover between competitors is only significant for the firms in the high-HHI industries: We have a strong transmission of environmental performance among competitors when few firms compete in the product market. These firms may face intense competitive threat from their rivals and lose market share if their environmental performance lags. In other words, if the product market is close to perfect competition and the market share is divided evenly among these firms, we find a weak adaptation of the firms to their competitors' environmental performance. Similar to the case of competitors, we find a larger supplier and customer effect when the focal firm is in a highly concentrated industry; it is significant for the transmission of environmental performance from suppliers at the 5% significance level, and for customers at 10%. The magnitude of the effect from customers is close to that from the suppliers, and both are weaker than the effect among competitors.

We also examine if the spillover between related firms is greater when environmental performance is of high relevance for the firms. We use industry environmental materiality from SASB to divide the sample in two groups: a group where both focal and related firms belong to industries with high environmental materiality, and a control group where neither the focal nor the related firm belongs to such industry. Columns (3) and (4) of Table 8 shows that the transmission of environmental performance is significant between competitors when they belong to industries with high materiality. The within R^2 of the competitor effect increases from 2.34% for the entire sample (see Table 4) to 3.62% when using only firms with high materiality.

Our results so far show that the transmission effect is stronger among competitors than through the supply chain. One motivation for this may be that the major competitive pressure is not through the supply chain. To see this, we focus now on firms in consumer-facing industries as the group most likely to face widespread pressure on environmental issues in the form of, for example,

boycotts. We consider the following GICS sectors as consumer-facing: consumer discretionary, consumer staples, healthcare and communication services. We expect the transmission effect to be especially strong in these sectors, as focal firms cannot afford to lag behind their related firms, lest they risk losing a significant portion of their customer base. Indeed, Columns (5) and (6) of Table 8 show that the coefficient on *EnvScr-R* is twice that of other sectors for competitors in consumer-facing sectors.[12] We find no significant differences for other relationship types, consistent with competitive pressure being the main driver of environmental-performance transmission.

3.5 Decomposing the Environmental Performance Spillover

In all the analyses so far, we focus on an aggregate measure of environmental performance, which reflects a combination of the firm's real outcomes (such as CO_2 emissions) and more declarative aspects (such as policies and targets). In this section, we examine transmission separately for real and declarative outcomes to better understand the drivers of the aggregate transmission effect. We study CO_2 emissions (in tonnes), which companies report annually to Asset4, to measure real outcomes. This helps alleviate concerns that *EnvScr* may be inflated due to "greenwashing." As a declarative measure, we use an indicator for whether a firm has, according to the assessment by Asset4 analysts, a policy for reducing emissions in the future. We examine four types of transmission.

1. CO_2 to CO_2: whether a related firm's CO_2 emissions affect the emissions of the focal firm
2. Policy to policy: whether the focal firm is more likely to adopt an emissions-reduction policy if the related firm already has one

[12] We also estimated the model with only consumer discretionary and consumer staples as consumer-facing industries. The competitor effect becomes stronger and highly significant for this group.

3. CO_2 to policy: whether a related firm's CO_2 emissions affect the adoption of an emissions-reduction policy by the focal firm
4. Policy to CO_2: the opposite cross-transmission, from a related firm's policy to the focal firm's CO_2 emissions

Table 9 summarizes the results—only the transmission coefficients, β, from Equation (2) are reported for brevity—for the four types of networks, as well as within each network separately for companies for which environmental issues are material. Among competitors, we find significant transmission for both CO_2 to CO_2 and policy to policy. The signs are positive, as would be expected. As far as cross-transmission, we find a significant policy-to-CO_2 effect. The sign is negative in this case, which also makes sense—if competitors adopt a policy for reducing emissions, it puts pressure on the focal firm to reduce its own emissions. The effect is generally stronger for the subsample of competitors for which environmental issues are material (though it is imprecisely estimated for policy to CO_2, due to the small number of observations).

For other types of networks, the transmission effect is mostly insignificant, except for the cross-transmission (policy to CO_2 and CO_2 to policy) from suppliers to customers. Finally, the negative policy-to-policy transmission effect from suppliers to customers is potentially puzzling. A possible explanation might be that if suppliers do not have any environmental policy, customers may be forced to impose policies to compensate for the negative reputational effect or to meet regulations.

4. Conclusion

In this paper, we study the corporate-network channel for environmental-performance propagation. We analyze the transmission effect from focal firms' competitors, customers, suppliers, and financial and operational partners. We find a significant environmental-performance spillover

between competitors. The degree of spillover depends on competitors' relative market share and number of connections in different networks. Our findings also show that the transmission of environmental performance depends on the level and direction of the changes in environmental performance. More specifically, we find that firms improve environmental performance when they have poor performance initially and their competitors improve theirs. In addition, we find significant spillover among competitors only in highly concentrated industries and in industries with high environmental materiality. The effect is stronger in consumer-facing industries as the group faces widespread pressure on environmental issues. Lastly, we document significant real effects of transmission from competitors using two outcomes: adoption of greenhouse-gas-emissions-reduction policies and changes in actual CO_2 emissions.

We do not find strong support for the environmental-performance transmission across other relationship types, on average, although we still find significant spillover when the focal firm is in a highly concentrated industry and when the related firm has a relatively stronger position in the network than the focal firm. In general, the magnitude of the effect from customers, suppliers, and partners is weaker than the effect from competitors.

Overall, we conclude that peer pressure among competitors is the main driver of environmental-performance transmission. Furthermore, well-connected firms spread their environmental policies and actions to other firms and those with few links are, in general, followers.

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Table 1. The list of the relationship categories and the number of links in each category

The table shows the 16 types of the relationships defined based on the FactSet Revere and the number of links used in our estimations. The data cover over 10,000 companies involved in over 155,000 relationships, including both direct (named by company) and reverse (named by other companies) relationships, retrieved from such sources as SEC 10-K annual filings, investor presentations, and press releases. Each relationship is assigned to one of the 16 categories. We group the 16 types of relationships into four categories: competitor, customer, supplier, and financial and operational partner.

Relationship	Number of links	Number of unique links
Competitors	115,853	37,568
Suppliers	72,223	29,944
Customers	88,299	35,963
Partners	79,873	18,180
In-Licensing	8,716	3,185
Manufacturing	2,349	872
Marketing	2,458	957
Distribution	3,341	1,354
Out-Licensing	9,378	3,524
Equity Investment	6,815	2,738
Investor	7,074	2,835
Joint Venture	18,162	5,255
Integrated Product	1,666	1,019
Research	26,647	13,021
Product Licensing	304	221
Technology	9,360	3,319
Other	427	290

Table 2: Sample statistics of the variables

The table reports the sample statistics of the variables. *EnvScr-F* is the focal companies' environmental score and *EnvScr-R* is the environmental score of the companies that are related to focal companies at least through one out of 16 forms of relationships reported in the FactSet database (see Table 1). *Size* is the logarithm of total assets. *Leverage* is the ratio of total debt to the book value of total assets. *R&D* is the ratio of research-and-development expenses to total sales. Tobin's *q* is market-to-book equity ratio, and *ROA* is return on assets. *MktShr-F* and *MktShr-R* represent the market shares of focal and related firms, respectively, and *NumLks-F* and *NumLks-R* stand for the total number of supply-chain, operational, and financial links between the focal and related firms. *KCntrl* is the Kleinberg measure of centrality of the focal and related firms (*Cntr-F, Cntr-R*). We drop the observations with negative equity values and winsorize the value of Tobin's *q* to 1% from above, and *R&D* and *ROA* to 1% from both sides. We have 302,437 observations over the period from 2004 to 2019.

	Mean	**Median**	**St. dev.**	**Min**	**Max**	**5%**	**10%**	**90%**	**95%**	**Skewness**	**Kurtosis**
EnvScr-F	50.4005	57.3509	31.2015	0.0000	98.9801	0.0000	0.0000	87.6984	91.3697	−0.3637	1.7803
EnvScr-R	46.2635	50.7946	30.6413	0.0000	99.0580	0.0000	0.0000	84.4114	89.6731	−0.1878	1.6875
Size	23.1037	23.1700	1.9076	14.1513	26.7425	19.7724	20.5205	25.5547	25.9589	−0.3032	2.4957
Leverage	0.2087	0.1996	0.1481	0.0000	0.8686	0.0000	0.0007	0.4122	0.4817	0.5540	3.0270
R&D	0.1626	0.0482	0.6019	0.0002	5.4720	0.0029	0.0058	0.2100	0.3028	7.7619	65.5104
Tobin's *q*	4.0596	2.5625	4.8295	0.0211	30.2646	0.7806	0.9953	8.0670	12.9577	3.3535	15.9693
ROA	3.7168	4.6697	10.6233	−46.0359	26.4420	−15.2746	−4.9941	13.4922	16.9390	−2.0868	10.4220
HHI	0.2542	0.1794	0.2193	0.0263	1.0000	0.0551	0.0708	0.5327	0.7708	1.8333	6.1607
MktShr-F	0.1283	0.0533	0.2132	0.0000	1.0000	0.0013	0.0033	0.3293	0.6252	2.8614	11.0678
MktShr-R	0.1539	0.0633	0.2383	0.0000	1.0000	0.0018	0.0046	0.4189	0.8772	2.4802	8.5833
NumLks-F	55.8889	31.0000	69.7972	0.0000	551.0000	3.0000	5.0000	140.0000	196.0000	2.7257	12.9415
NumLks-R	48.0564	27.0000	61.3604	0.0000	551.0000	3.0000	5.0000	115.0000	175.0000	2.9686	14.9025
KCntrl-F (supp.)	0.0107	0.0004	0.0254	0.0000	0.7038	0.0000	0.0000	0.0346	0.0586	4.8248	48.3599
KCntrl-F (cust.)	0.0188	0.0031	0.0353	0.0000	0.4999	0.0000	0.0000	0.0646	0.0969	2.7260	11.1856
KCntrl-R (supp.)	0.0094	0.0003	0.0237	0.0000	0.7070	0.0000	0.0000	0.0559	0.0509	4.8832	42.2700
KCntrl-R (cust.)	0.0169	0.0029	0.0330	0.0000	0.4999	0.0000	0.0000	0.0296	0.0894	3.0979	15.1075
Env Materiality	1.9758	1.0000	1.9358	0.0000	6.0000	0.0000	0.0000	5.0000	5.0000	0.5675	1.8899

Table 3: Estimation results for the baseline model

The table reports the result of the pair fixed-effect estimation of the regression model with the focal companies' environmental score (*EnvScr-F*) as the dependent variable and one-year lagged environmental score (*EnvScr-R*) of companies related to the focal company through at least one of 16 forms of relationships reported in the FactSet database as the independent variable. The model also includes the lagged values of five control variables: the logarithm of total assets (*Size*), the ratio of total debt to the book value of total assets (*Leverage*), the ratio of research and development expenses to total sales (*R&D*), the market-to-book equity ratio (Tobin's *q*), and the return on assets (*ROA*), as well as year dummies. Column (1) shows the estimation with no interaction term, Columns (2) to (4) show the estimations including the interaction terms with focal- and related-firm market shares (*MktShr-F, MktShr-R*) and their total number of supply-chain, operational, and financial links (*NumLks-F, NumLks-R*). Column (5) shows the result of the complete model by including the lagged values of focal firms' *EnvScr* as a regressor. The data cover the period from 2004 to 2019. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)
EnvScr-F (lagged)					0.4972***
					(0.0039)
EnvScr-R	0.0116***	0.0162***	0.0402***	0.0475***	0.0238***
	(0.0039)	(0.0044)	(0.0053)	(0.0058)	(0.0038)
EnvScr-R × MktShr-F		−0.0273***		−0.0367***	−0.0133**
		(0.0072)		(0.0073)	(0.0053)
EnvScr-R × NumLks-F			−0.0007***	−0.0007***	−0.0005***
			(0.0001)	(0.0001)	(0.0000)
EnvScr-R × MktShr-R		0.0025		−0.0033	−0.0021
		(0.0061)		(0.0062)	(0.0045)
EnvScr-R × NumLks-R			0.0003***	0.0002***	0.0002***
			(0.0001)	(0.0001)	(0.0000)
MktShr-F		0.6875		1.3150***	−0.1805
		(0.4546)		(0.4626)	(0.3401)
NumLks-F			0.0371***	0.0382***	0.0213***
			(0.0039)	(0.0040)	(0.0024)
MktShr-R		0.7425**		0.9821***	0.4844**
		(0.3132)		(0.3165)	(0.2384)
NumLks-R			−0.0087	−0.0070	−0.0083**
			(0.0054)	(0.0054)	(0.0036)
Size	5.0016***	5.5855***	5.4113***	5.4280***	3.4031***
	(0.1952)	(0.2162)	(0.2103)	(0.2106)	(0.1308)
Leverage	−3.2452***	−4.3543***	−3.9320***	−4.0251***	−3.9940***
	(0.5924)	(0.6474)	(0.6450)	(0.6448)	(0.4141)
R&D	0.4296***	0.5355***	0.5240***	0.5253***	0.3351***
	(0.0888)	(0.0995)	(0.0989)	(0.0990)	(0.0684)
Tobin's *q*	0.0206	0.0299*	0.0227	0.0238	0.0669***
	(0.0137)	(0.0153)	(0.0148)	(0.0148)	(0.0099)
ROA	0.0580***	0.0627***	0.0613***	0.0612***	0.0499***
	(0.0049)	(0.0056)	(0.0056)	(0.0056)	(0.0037)
Observations	261,567	222,795	223,039	222,795	222,719
R^2 within	0.0205	0.0245	0.0291	0.0296	0.277
R^2 total	0.9388	0.9385	0.9389	0.9389	0.9544

Table 4. Comparing the *EnvScr* spillover across different relationships

The table reports the result of the pair fixed-effect estimation of the regression model with focal companies' environmental score as the dependent variable and one-year lagged related companies' environmental score (*EnvScr-R*)—competitors, customers, suppliers or financial and operational partners—as the independent variable. The model also includes the lagged values of five control variables: the logarithm of total assets (*Size*), the ratio of total debt to the book value of total assets (*Leverage*), the ratio of research and development expenses to total sales (*R&D*), the market-to-book equity ratio (Tobin's *q*), and the return on assets (*ROA*), as well as year dummies. The data cover the period from 2004 to 2019. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Competitor effect	**Customer effect**	**Supplier effect**	**Partner effect**
EnvScr-R	0.0244***	0.0093	0.0052	0.0007
	(0.0065)	(0.0072)	(0.0066)	(0.0070)
Size	5.1333***	3.9506***	5.0599***	5.5693***
	(0.3108)	(0.3708)	(0.4051)	(0.3951)
Leverage	−1.5259	−3.4642***	−6.2465***	−4.5578***
	(0.9345)	(1.1064)	(1.1388)	(1.1467)
R&D	0.1977**	0.8899***	1.3496***	0.8227***
	(0.0845)	(0.2255)	(0.3728)	(0.2197)
Tobin's *q*	0.0473**	−0.1026***	0.1075***	0.0560**
	(0.0215)	(0.0211)	(0.0270)	(0.0270)
ROA	0.0663***	0.0586***	0.0540***	0.0645***
	(0.0073)	(0.0088)	(0.0110)	(0.0095)
Observations	115,853	88,299	72,223	79,873
Pairs	37,568	35,963	29,944	28,330
R^2 within	0.0234	0.0159	0.0192	0.0223
R^2 total	0.9350	0.9451	0.9473	0.9359

Table 5. Relative importance of companies based on market share and number of links

The table reports the results of the pair fixed-effect estimation of the regression model with focal companies' *EnvScr* as the dependent variable and one-year lagged related companies' environmetal score (*EnvScr-R*)—competitor, customer, supplier or financial and operational partner—as the independent variable. The model also includes the lagged values of five control variables: the logarithm of total assets (*Size*), the ratio of total debt to the book value of total assets (*Leverage*), the ratio of research and development expenses to total sales (*R&D*), the market-to-book equity ratio (Tobin's *q*), and the return on assets (*ROA*), as well as year dummies. For the sake of space, we do not report the results for the control variables. All the estimations include the interaction terms with the focal and related firms' market shares (*MktShr-F, MktShr-R*) and total number of supply-chain, operational, and financial links of the focal and related firms (*NumLks-F, NumLks-R*). The data cover the period from 2004 to 2019. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Competitor effect	**Customer effect**	**Supplier effect**	**Partner effect**
EnvScr-R	0.0513***	0.0266**	0.0423***	0.0314***
	(0.0091)	(0.0114)	(0.0104)	(0.0116)
EnvScr-R × MktShr-F	−0.0096	−0.0349**	0.0135	−0.0557***
	(0.0149)	(0.0147)	(0.0132)	(0.0120)
EnvScr-R × NumLks-F	−0.0009***	−0.0004***	−0.0006***	−0.0005***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
EnvScr-R × MktShr-R	0.0318**	−0.0164	−0.0167*	0.0062
	(0.0150)	(0.0114)	(0.0101)	(0.0109)
EnvScr-R × NumLks-R	0.0003***	0.0002**	0.0002**	0.0002*
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
MktShr-F	−0.9345	0.0933	−1.2551	3.4158***
	(0.8999)	(0.9773)	(0.8086)	(0.7953)
NumLks-F	0.0525***	0.0088	0.0589***	0.0152*
	(0.0074)	(0.0072)	(0.0068)	(0.0080)
MktShr-R	−1.0539	1.2708**	1.3931***	0.4247
	(0.7602)	(0.6004)	(0.5199)	(0.5931)
NumLks-R	−0.0181*	−0.0091	−0.0072	−0.0154
	(0.0102)	(0.0100)	(0.0079)	(0.0116)
Control variables	Yes	Yes	Yes	Yes
Observations	86,628	61,920	50,519	60,571
R^2 within	0.0350	0.0209	0.0358	0.0325
R^2 total	0.9343	0.9457	0.9485	0.9362

Table 6. Relative importance of companies based on supply chain relationships

The table reports the result of the pair fixed-effect estimation of the regression model with focal companies' environmental score as the dependent variable and one-year lagged related companies' environmental score (*EnvScr-R*)—customer or supplier—as the independent variable. The model also includes the lagged values of five control variables: the logarithm of total assets (*Size*), the ratio of total debt to the book value of total assets (*Leverage*), the ratio of research and development expenses to total sales (*R&D*), the market-to-book equity ratio (Tobin's *q*), and the return on assets (*ROA*), as well as year dummies. For the sake of space, we do not report the result for the control variables. All the estimations include the interaction terms with the focal and related firms' market shares (*MktShr-F, MktShr-R*) and a measure of centrality of the focal and related firms (*Cntr-F, Cntr-R*). In the first two columns, centrality is measured using Kleinberg centrality; in the last two columns, we use the total number of suppliers (customers) for customers (suppliers) as the measure of their centrality in the network. The data cover the period from 2004 to 2019. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Kleinberg centrality		**Number of links**	
	Customer effect	**Supplier effect**	**Customer effect**	**Supplier effect**
EnvScr-R	0.0050	0.0125	0.0126	0.0354***
	(0.0100)	(0.0089)	(0.0105)	(0.0098)
EnvScr-R × MktShr-F	−0.0309**	0.0188	−0.0309**	0.0163
	(0.0147)	(0.0129)	(0.0147)	(0.0131)
EnvScr-R × Cntr-F	0.1340	−0.3962***	−0.0002	−0.0009***
	(0.1246)	(0.0849)	(0.0002)	(0.0001)
EnvScr-R × MktShr-R	−0.0155	−0.0093	−0.0151	−0.0177*
	(0.0114)	(0.0100)	(0.0115)	(0.0101)
EnvScr-R × Cntr-R	0.1430	0.3018***	0.0003*	0.0003**
	(0.1137)	(0.1065)	(0.0002)	(0.0001)
MktShr-F	0.0179	−1.3302*	−0.0554	−1.4796*
	(0.9788)	(0.7959)	(0.9745)	(0.8059)
Cntr-F	4.4080	48.4302***	0.0081	0.0755***
	(8.0857)	(5.2811)	(0.0124)	(0.0105)
MktShr-R	1.3509**	1.0093**	1.2594**	1.3894***
	(0.5959)	(0.5098)	(0.6030)	(0.5163)
Cntr-R	−8.8525	−16.9381***	−0.0045	−0.0107
	(9.6037)	(5.9821)	(0.0155)	(0.0081)
Control variables	Yes	Yes	Yes	Yes
Observations	61,920	50,519	61,920	50,519
R^2 within	0.0193	0.0318	0.0193	0.0307
R^2 total	0.9456	0.9483	0.9456	0.9483

Table 7. Comparing *EnvScr* spillover based on the level and direction of change

The table reports the results of the pair fixed-effect estimation of the regression model with focal companies' *EnvScr* as the dependent variable and one-year lagged related companies' environmental score (*EnvScr-R*)—competitor, customer, supplier, or financial and operational partner—as the independent variable. The first two columns divide the sample based on the lagged focal-firm environmental scores. Columns (3) to (6) divide each of the low and high groups in two groups based on the direction of the change in environmental performance (decrease and increase). All separations are based on the median values. The model also includes the lagged values of five control variables (see Table 4) and year dummies. The results of the control variables are not reported. The data cover the period from 2004 to 2019. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

		Environmental Score		High Environmental Score		Low Environmental Score	
		High	**Low**	**Decrease**	**Increase**	**Decrease**	**Increase**
Competitor effect	*EnvScr-R*	0.0083	0.0272***	0.0103	0.0029	0.0134	0.0343***
		(0.0055)	(0.0077)	(0.0096)	(0.0073)	(0.0148)	(0.0101)
	Observations	45,765	54,021	16,802	22,052	19,287	24,854
	R^2 within	0.0049	0.0100	0.0047	0.0059	0.0110	0.0103
Customer effect	*EnvScr-R*	0.0088	0.0103	0.0077	0.0049	0.0008	0.0170
		(0.0064)	(0.0081)	(0.0124)	(0.0091)	(0.0171)	(0.0112)
	Observations	29,447	40,608	10,098	13,679	12,669	19,184
	R^2 within	0.0071	0.0102	0.0084	0.0078	0.0099	0.0111
***Supplier* effect**	*EnvScr-R*	0.0020	0.0190*	0.0096	−0.0006	0.0154	0.0221
		(0.0052)	(0.0103)	(0.0097)	(0.0073)	(0.0212)	(0.0136)
	Observations	36,337	20,448	12,221	16,947	6,775	9,030
	R^2 within	0.0068	0.0168	0.0046	0.0085	0.0165	0.0164
***Partner* effect**	*EnvScr-R*	−0.0028	0.0156*	0.0001	−0.0093	−0.0088	0.0177
		(0.0055)	(0.0088)	(0.0097)	(0.0080)	(0.0159)	(0.0119)
	Observations	35,930	30,850	13,134	16,891	10,576	14,122
	R^2 within	0.0069	0.0129	0.0074	0.0057	0.0144	0.0159

Table 8. Comparing *EnvScr* spillover across different relationships for samples divided by industry characteristics

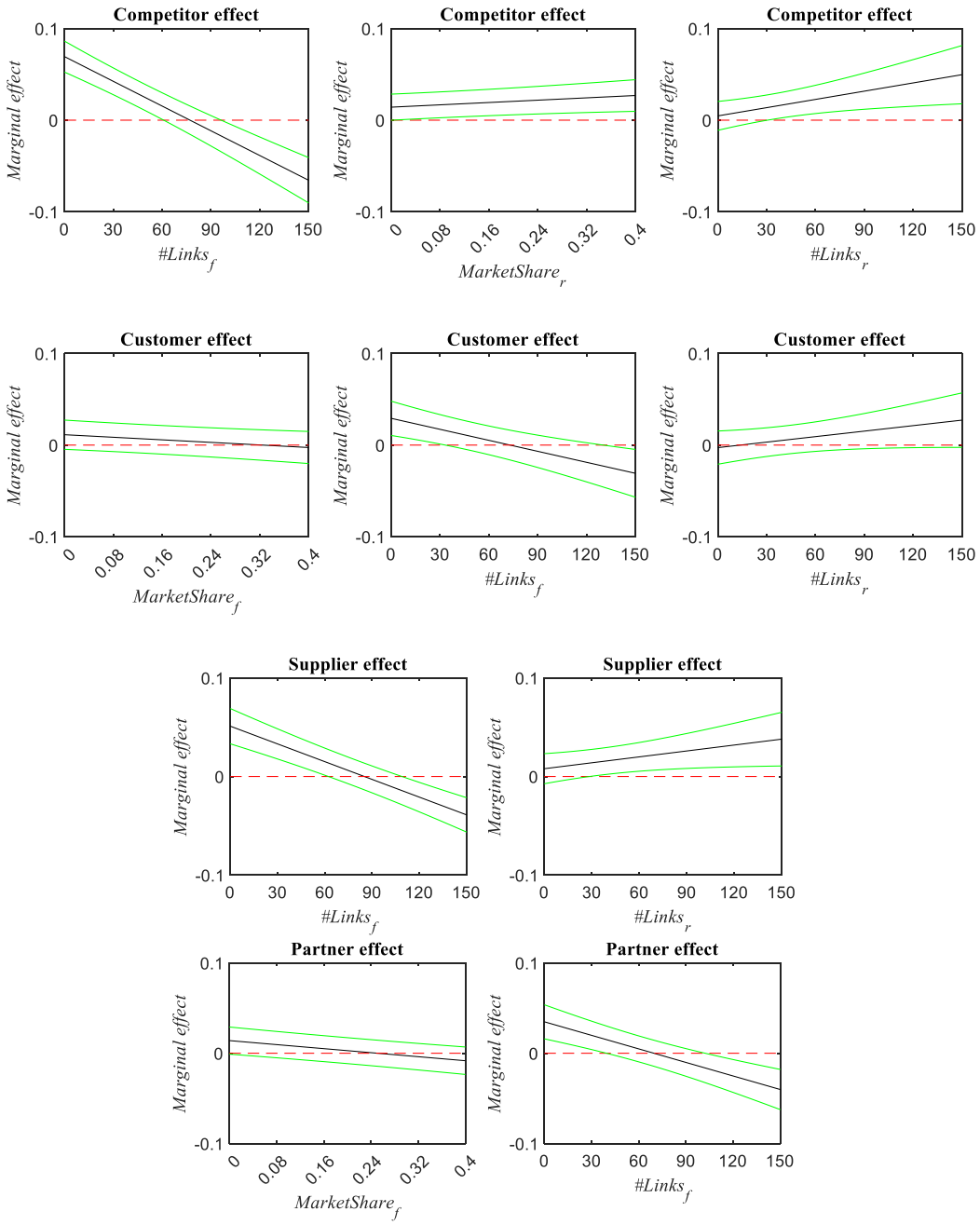
The table reports the results of the pair fixed-effect estimation of the regression model with the focal companies' *EnvScr* as the dependent variable and the one-year lagged related companies' environmental score (*EnvScr-R*)—competitor, customer, supplier, or financial and operational partner—as the independent variable. The first two columns divide the sample based on the focal firms' industry concentration (*HHI*). Columns (3) and (4) divide the sample in a group where both focal and related firms belong to industries with high environmental materiality, and a control group where neither do. The last two columns of the table divide the firms in two groups, a group that belongs to industries that sells mostly to households (consumer) and a group that sells mostly to other customer types (other). The first group consists of consumer discretionary, consumer staples, communication services, and healthcare. The model also includes the lagged values of five control variables (see Table 4) and year dummies. The results of the control variables are not reported. The data cover the period from 2004 to 2019. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

		HHI		Materiality		Customer type	
		High	**Low**	**High**	**Low**	**Consumer**	**Other**
Competitor effect	*EnvScr-R*	0.0552***	0.0094	0.0361***	0.0149	0.0364**	0.0142*
		(0.0128)	(0.0074)	(0.0082)	(0.0096)	(0.0142)	(0.0073)
	Observations	32,604	65,477	47,509	55,218	26,782	75,963
	R^2 within	0.0098	0.0358	0.0362	0.0202	0.0452	0.0154
Customer effect	*EnvScr-R*	0.0213*	−0.0014	0.0019	0.0150	−0.0032	0.0095
		(0.0111)	(0.0099)	(0.0094)	(0.0107)	(0.0166)	(0.0081)
	Observations	35,611	32,872	34,808	37,868	14,107	58,572
	R R^2 within	0.0123	0.0256	0.0200	0.0173	0.0175	0.0153
***Supplier* effect**	*EnvScr-R*	0.0234**	−0.0023	0.0027	0.0020	−0.0189	0.0059
		(0.0119)	(0.0077)	(0.0087)	(0.0093)	(0.0157)	(0.0071)
	Observations	19,934	36,022	29,421	29,670	10,518	48,573
	R^2 within	0.0081	0.0276	0.0346	0.0151	0.0642	0.0113
***Partner* effect**	*EnvScr-R*	0.0149	−0.0090	0.0078	−0.0078	−0.0273*	−0.0005
		(0.0118)	(0.0087)	(0.0087)	(0.0103)	(0.0166)	(0.0077)
	Observations	32,038	33,744	32,924	36,283	14,271	54,939
	R^2 within	0.0105	0.0348	0.0206	0.0208	0.0293	0.0192

Table 9. Disaggregating the transmission effect of environmental performance

The table reports the result of the pair fixed-effect estimation of the transmission effect for two specific measures of environmental performance: actual CO_2 emissions reported by the company and an indicator variable for whether the company has a policy for reducing future emissions, according to Asset4 analysts. These measures are components of the aggregate environmental score (*EnvScr*) used in previous analyses. The dependent variable is the focal firm's CO_2 Emissions (Emissions Policy), and the key independent variable is the related firm's lagged CO_2 Emissions (Emissions Policy). Firms can be related either as competitors, customers, suppliers, or partners. For each type of relationship, we separately examine focal and related firms for which environmental issues are material. We model four types of transmission: CO_2 to CO_2, policy to policy, policy to CO_2, and CO_2 to policy. The model also includes the lagged values of five control variables (see Table 4) and year dummies. The results for the control variables are not reported. The data cover the period from 2004 to 2019. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

		CO_2 Emissions				**Emissions Policy**			
		All	**Material**	**All**	**Material**	**All**	**Material**	**All**	**Material**
Competitors	*Emission-R*	0.0022*	0.0056**			0.0081	0.0020		
		(0.0013)	(0.0023)			(0.0075)	(0.0102)		
	Policy-R			−0.0016***	−0.0035			0.0145**	0.0329***
				(0.0006)	(0.0019)			(0.0057)	(0.0120)
	Observations	40,719	13,374	65,068	18,702	62,761	17,196	102,838	25,135
	R^2 within	0.7070	0.7690	0.7430	0.7990	0.0169	0.0046	0.0152	0.0088
Customers	*Emission-R*	0.0011	0.0068			0.0066	0.0259		
		(0.0010)	(0.0057)			(0.0112)	(0.0639)		
	Policy-R			0.0006	0.0034			−0.0046	0.0074
				(0.0004)	(0.0023)			(0.0069)	(0.0189)
	Observations	28,849	4,581	42,776	6,018	49,958	6,419	72,772	8,407
	R^2 within	0.0005	0.0005	0.0007	0.0014	0.0224	0.0124	0.0208	0.0092
Suppliers	*Emission-R*	0.0048	0.0025			−0.0009***	−0.0006***		
		(0.0030)	(0.0029)			(0.0003)	(0.0002)		
	Policy-R			−0.0010**	−0.0027			−0.0132***	−0.0111
				(0.0004)	(0.0019)			(0.0051)	(0.0088)
	Observations	25,932	5,172	46,844	8,581	33,014	6,091	59,165	9,986
	R^2 within	0.2790	0.6890	0.1890	0.5280	0.0212	0.0057	0.0168	0.0081
Partners	*Emission-R*	0.0014	0.0041			0.0004	0.0115		
		(0.0009)	(0.0028)			(0.0141)	(0.0168)		
	Policy-R			0.0011	0.0043			0.0044	0.0158
				(0.0012)	(0.0052)			(0.0069)	(0.0139)
	Observations	35,631	10,890	49,642	13,220	48,730	12,570	69,263	15,439
	R^2 within	0.1040	0.1750	0.0769	0.1510	0.0189	0.0070	0.0136	0.0076

Figure 1. Marginal effect of related firms *EnvScr* for different levels of market share and the number of links

The figure illustrates the marginal effects of the related firms' lagged *EnvScr* for different levels of market share and the number of links of focal and related firms, calculated for the estimations in Table 5. We only show the marginal effect of the significant interaction terms. The dotted lines are the 95% confidence intervals of the marginal effect.