# Green links: Corporate networks and environmental performance*

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**Abstract**

We investigate how environmental performance propagates in corporate networks. We focus on the propagation of changes in carbon intensity among competitors as well as in customer–supplier relationships. We find evidence of a causal effect among competitors, while the propagation from customers to suppliers and vice versa appears to be explained by industry trends. The competitor effect is strongest in industries that are highly concentrated and for which environmental issues are financially material. Stronger firms, as measured by market share and total number of links are less affected by the actions of their peers. Importantly, we find that the effect on the focal firm is stronger if the focal firm's own carbon intensity is high initially. Overall, network effects among competing firms are a significant force shaping their environmental performance, and a force mostly for good.

**Keywords:** Environmental Performance, Carbon Intensity, Corporate Network, Competitive Effect, Technological Spillover

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# 1. Introduction

Climate change is an existential challenge to humanity, requiring urgent action to reduce CO2 emissions and the environmental impact of economic activity. Accordingly, environmental issues play an increasingly important role for corporations, both in terms of public attention and regulation stringency. Importantly, companies need to be concerned about not just their own environmental performance, but also that of other companies in their networks. On one hand, implementation of environmentally friendly policies may create a competitive advantage for firms competing in the same product market by attracting customers from other firms producing the same product, which in turn may force those other firms to also implement such policies. On the other hand, companies are exposed to environmental risks created by their customers and suppliers. Through such channels, corporate networks can play an important role in spreading environmental policies and actions around the globe.[1]

In this paper, we analyze comprehensive data on different types of linkages among companies worldwide to investigate how the environmental performance of a firm is affected by that of its competitors, customers, and suppliers. We focus on an objective measure of environmental performance, carbon intensity, defined as companies' CO2 emission scaled by revenue, as it captures firms' real actions to tackle climate change. For comparability with earlier studies, such as Schiller (2018), we also conduct our baseline analysis using a broad measure of environmental performance, the Environmental Pillar Score from Asset4, which also includes "declarative"

[1] Earlier studies have shown corporate networks to be conduits to 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 Roberts, 2014; Chu and Wang, 2017; Oliveira et al., 2017), trade credit (Zhang et al., 2020), and tax avoidance (Cen et al., 2017). Most closely related to this paper, Schiller (2018) and Dai et al. (2021) document that corporate customers have a statistically significant and economically meaningful effect on their suppliers' environmental and social performance.

aspects, such as policies and targets. Due to technological barriers to reduce emissions, we expect it to be more feasible to improve “declarative” outcomes than “real” outcomes like actual emissions reduction. Therefore, declarative outcomes may be inflated due to “greenwashing”, and firms may adapt their environmental performance related to these outcomes, even to their potential competitors, suppliers and customers, without being involved in an active relationship. This should be less likely for the propagation of the real outcome measure, carbon intensity.

We find that peer pressure from competitors is the most significant channel for the propagation of environmental performance in terms of carbon intensity. It remains robust to adjustment for industry trends and to two different identification strategies: a quasi-natural experiment involving environmental regulation at the country level and a placebo test of propagation among companies outside their “active” relationship period. When it comes to propagation from customers to suppliers or vice versa, the baseline effects are not robust: They are either subsumed by industry trends or do not survive the identification tests. Thus, the only arguably causal peer effect we find is among competing firms.

We further investigate whether the propagation of carbon performance among competitors is due to competitive pressure or stems from technological spillover, or whether both forces are at play. Competitive effects should be stronger in highly concentrated industries, since firms in such industries are subject to more scrutiny, forcing them to improve their carbon performance if rivals do so. Similarly, firms with less market and bargaining power should also be more sensitive to their competitors’ action, for risk of losing customers and market share. We find that the propagation of carbon performance is indeed stronger for firms in more concentrated industries and firms with less market and bargaining power than their competitors, underscoring the importance of competitive threat.[2]

On the other hand, we expect technological spillover to be greater in industries where environmental issues are of high relevance to firms' financial performance. This is because firms in such industries have a greater incentive to innovate on those issues. We use the industry-level materiality map from the Sustainability Accounting Standards Board (SASB) to identify environmentally sensitive industries and find that the propagation of carbon performance is indeed stronger among firms belonging to those industries. We also find that network propagation leads to improvements in carbon performance as the effect is strong when the competitor reduces its carbon intensity and when the focal firm's carbon intensity is high initially.

Our results suggest that, to maximize the "ripple effects" of environmental performance across the corporate network, regulators, activists, and other interested stakeholders should focus on firms with large market and bargaining power 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 improvements in environmental performance. 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 propagation acts to improve firms' environmental performance, in terms of real outcomes, such as reducing carbon intensity.

[2] Schiller (2018) also shows that propagation from customers to suppliers is stronger when customers have greater bargaining power and suppliers are in countries with lower ESG standards.

Our work sits at the crossroads of the emerging literature on sustainable finance and propagation 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 lead 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 propagate 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 propagation of corporate decisions among industry peers. Leary and Roberts (2014), among others, 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.

One underexamined question in the literature on corporate networks is whether the adoption of environmentally friendly practices propagates to economically linked firms. The two most closely related studies are Schiller (2018), who uses similar data to construct proprietary indices of corporate environmental and social performance and investigate the role of supply-chain relationships for the propagation of corporate environmental and social performance, and Dai et al. (2021), who investigate the transmission of socially responsible behavior of firms linked through the supply chain and find a unilateral effect only from customers to suppliers. Furthermore, Cao et al. (2019) study the propagation of firms' corporate social-responsibility adoption within U.S. firms' competitor 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. We contribute to these studies by focusing on carbon performance and comparing the relative importance of companies' different product-market interactions for propagation of environmental performance. We show that the competitor network, rather than the supply-chain network, channels the propagation of carbon performance.

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 argument, firms' focus on environmental, social, and governance (ESG)-related performance leads to a "wrong" corporate objective function. That is, firms should focus on profits and shareholder value rather than social responsibility (Friedman, 2007; Reich, 2008; Karnani, 2010). Therefore, firms' engagement in environmental action must be motivated. Bénabou and Tirole (2010) offer a theoretical framework for why companies might engage in ESG activities.[3] Empirical studies document different incentives for firms' ESG activities, broadly consistent with the above framework: relaxed financial constraints , shareholder engagement and active ownership (Akey and Appel, 2019; Dimson et al., 2021; Dyck et al., 2019; Naaraayanan et al., 2020), managerial agency problems (Bertrand and Mullainathan, 2003; Cronqvist et al., 2009; Cheng et al., 2013), avoiding reputational risks (Hong et al., 2019), and such strategic implications as competitive advantage (Baron, 2001; McWilliams et al., 2006). Common to these studies is that they take a standalone view of the firm. By contrast, in this paper, we investigate a new and relatively under-

[3] They suggest three distinct motivations for companies' engagement in ESG activities: (i) "Doing well by doing good," whereby companies adopt a long-term perspective that maximizes environmental and social welfare as well as profits; (ii) "Delegated philanthropy," meaning companies undertake ESG on behalf of stakeholders; and (iii) "Insider-initiated corporate philanthropy," in which corporate ESG reflects managements' or the board members' own desires to engage in philanthropy.

examined channel: propagation across corporate networks in which firms alter their own environmental performance because other firms do so.

The rest of the paper is organized as follows. In Section 2, we discuss the conceptual framework that motivates our hypotheses. In Section 3, we describe the data. Section 4 presents the results from our baseline analysis. In Section 5, we argue for a causal effect of firm relationships. Section 6 analyses the propagation channels of environmental performance. Section 7 concludes.

# 2. Conceptual Framework

No firm operates in a vacuum. Thus, not only its own environmental performance matters, but also the environmental performance of firms related to it. In this section, we outline the basic mechanisms we expect to drive environmental-performance propagation among related firms.

### 2.1 Propagation between competitors

Consider, first, firms competing in the same product market. Several factors may affect environmental-performance propagation among such firms. The first two factors are related to the firms' technological positions, technological opportunity and technological spillover (Jaffe, 1986). Technological opportunity stems from industry-specific or economy-wide exogenous variations in the cost and difficulty of technological innovations. Low-carbon innovations relating to mobility, buildings and cities, food, and energy supply and distribution are examples of technological opportunities related to environmental performance (see Tyfield and Jin, 2010; Geels, 2018; Wilson, 2018; Wilson et al., 2019, for examples). Technological opportunity may bring about market transitions, forcing firms in the same industry to adopt the same actions, such as the automobile industry switching to electric vehicles from those powered by fossil fuels, moderating climate change (Barkenbus, 2009). Technological spillover, according to Jaffe (1986), stems from information and knowledge exchange among firms who have research and development projects on similar technologies. This spillover allows the firms to adopt new low-carbon technology with less effort (see also Griliches, 1979, for the effects of spillover of knowledge capital on within-industry productivity). In addition, competing firms' environmental policies may be driven in the same direction by economy- and industry-wide regulations.

Another important factor for the propagation of environmental action among competing firms is the so-called competitive or business-stealing effect, which arises when market shares and profits are redistributed among rivals as a result of some of them switching to new production or marketing strategies.[4] In our context, the competitive effect is related to firms' willingness to improve their environmental performance to increase market share in the output market and gain favorable conditions in the input market. More specifically, if companies' corporate partners (e.g., customers and investors) are concerned about climate change, then, all else being equal, they will prefer to engage with more environmentally friendly firms. As a result, if one firm improves its environmental performance, then its competitors will be negatively affected even if their own environmental performance does not change. Thus, what matters for a firm is not only its own environmental performance in absolute terms, but also relative to its competitors. Such competitive pressure provides a clear incentive for firms to monitor and respond to changes in their competitors' environmental performance.

Our study focuses on interactions between firms that explicitly consider each other as competitors. By controlling for industry-wide common trends in environmental action, our measured

[4] Lang and Stulz (1992) use the term "contagion effect" to explain the positive interdependence between the rival firms' values, due to being exposed to similar industry-wide business risks. The "competitive effect," on the other hand, is attributed to wealth redistribution among rivals (see also Jorion and Zhang, 2007). Bloom et al. (2013) and Lucking et al. (2018) identify the business-stealing effect on firms' value of product-market rivals' R&D.

propagation of environmental performance among competing firms reflects the competitive effect as well as firm-pair technology spillover in excess of industry-wide trends.

## 2.2 Propagation through supply chains

Previous studies (W. M. Cohen et al., 2002, Belderbos et al., 2004, Isaksson et al., 2016) show that knowledge can be exchanged between upstream and downstream supply-chain partners. Thus, supply-chain partners may share knowhow and information about environmental practices. Another channel is reputational risk. In this context, even if a firm is careful about its own direct environmental impact, being linked to a supplier with poor environmental performance will still reflect poorly on the firm.[5] Investors pay increasing attention to supply-chain environmental risks, which motivates customer companies to ensure that improvements in their own environmental performance are also implemented by their suppliers. While the risk faced by customer firms from their suppliers has received the bulk of attention, the same mechanism could operate in the opposite direction. A supplier firm with high environmental standards could be concerned about selling to customers with low standards and try to influence them to improve.

## 2.3 Comparing channels

How should we think about the relative importance of competitor versus supply-chain effects? Actions by competitors directly change the relative environmental performance of a focal firm—a first-order effect. In contrast, from a supplier's perspective, the environmental concerns of its customers may result in pressure to improve, but they do not on their own change how this supplier

[5] McKinsey (2016) reports, "The typical consumer company's supply chain creates far greater social and environmental costs than its own operations, accounting for more than 80 percent of greenhouse-gas emissions and more than 90 percent of the impact on air, land, water, biodiversity, and geological resources (Exhibit 3)."

compares to other potential suppliers. Thus, the customer-to-supplier propagation is likely to be second order. The same logic applies to the effect a supplier may have on its customers.

Another relevant dimension is transparency of the different relationships and, consequently, the attention they receive from outside stakeholders. Consumers and investors are likely quite well aware of which firms compete in a given product market, making relative environmental performance among competitors transparent. Supply-chain relationships are more complex and opaque, making this dimension of environmental performance more difficult to track for outsiders. Thus, we expect changes in environmental performance of competitors to be the most salient and to result in the strongest propagation effect.

Furthermore, competing firms tend to have similar technology spaces, making it easier for them to adopt each other's new technologies (Jaffe, 1986). Therefore, we expect technology spillover in environmental performance to be stronger between competing firms than between supply-chain partners.

## 3. Data

We combine three kinds of data in our main analysis spanning 2004 to 2019: corporate relationships from FactSet Revere, environmental performance from Asset4, and accounting data from Eikon. We discuss the data sources and summary statistics of our sample below. All variables are defined in Table A1 in the Appendix.

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 16 categories.[6] Following our conceptual framework laid out in Section 2, we focus on competitor and customer–supplier relationships. Company *r* is defined as a competitor, customer or supplier of focal company *f* if either reports the relationship in FactSet. These three categories jointly account for the vast majority of reported relationships.

For each firm pair, FactSet also reports the first and last years of a given relationship type reported by at least one of the firms. We use this information to form our "active" sample, that is firm-pair years falling within the reported period, and the "inactive" sample, which contains firm-pair years outside the reported relationship period and for which we could obtain the required environmental and accounting data. Comparing the active and inactive samples is one of our strategies for establishing causality in the propagation from related to focal firms (see Section 5 for details).

We are interested in the propagation of environmental performance, which we capture primarily with carbon intensity, measured by CO2 emissions in tons scaled by revenue in USD million (*CO2toRev*). In addition, and for comparability with earlier studies, we also consider the Environment Pillar Score (*EnvScr*) in some of our analyses. Both metrics come from Asset4, a major providers of ESG data, covering more than 10,000 companies worldwide. The *EnvScr* combines three category scores - emissions, resource use, and innovation - based, in turn, on 68 individual metrics. Thus, the *EnvScr* aims to broadly capture a firm's environmental performance.

We include a set of control variables at the firm level: *Size*, defined as the logarithm of total assets; *Leverage,* defined as the ratio of total debt to the book value of total assets; *Sales Turnover*, defined as the ratio of total sales to total assets; *Tobin's q*, defined as the market value of equity to book value of equity; and *Return on Assets* (*ROA*), a measure of profitability. According to Schiller

[6] In addition to competitors, suppliers and customers, the relationship categories include partnerships: in-licensing, manufacturing, marketing, distribution, out-licensing, equity investment, investor, joint venture, integrated product, research, product licensing, technology, and other.

(2018), these characteristics drive the firm's environmental performance.[7] They may also indirectly drive environmental performance of related firms, since the characteristics of focal and related firms are likely correlated because of (1) assortative matching of related firms by such characteristics as size and performance (see Dragusanu, 2014; Sugita et al., 2021) and (2) transmission of such corporate policies as leverage decisions through corporate networks (e.g., Chu and Wang, 2017; Oliveira et al., 2017). Hence, to isolate the effect of propagation from related firms to the focal firm, we control for the focal firm's own characteristics and those of related firms. Furthermore, we define two control variables at the country level, based on the location of firms' headquarters: *GDPperCap*, in USD thousand (logged), capturing the wealth of a country, and *CO2toGDP*, defined as CO2 emissions in kilograms per PPP $ of GDP, measuring the overall carbon intensity of the economy. We control for *GDPperCap* and *CO2toGDP* of the focal firm and the related firm country of headquarters.

We also consider a number of characteristics at the firm and industry levels that may moderate the propagation of environmental performance. We measure market power with the firm's *Size* as defined above and the market share (*MktShr*), calculated as the ratio of the firm's total sales to the sum of the total sales of all firms competing in the same market as the focal company, based on the FactSet definition of competitor firms. We also measure a firm's bargaining power in the supply chain with the firm's number of links (*NumLks*) and its network-centrality scores. *NumLks* for each firm is defined as the total number of firms linked to a firm as customers or suppliers and indicates firms' overall bargaining power in the input and output markets. Note that even if two firms are related through more than one relationship (e.g., firm *r* is both a customer and a supplier of firm *f*), we count that as one link between the two. Thus, the network we consider is unweighted.

[7] Schiller (2018) uses the book-to-market ratio, which is the inverse of *Tobin's q*.

To separate customer bargaining power from supplier bargaining power, we use supply-chain centrality measures (*KCntrl;* Kleinberg, 1999) to assess the relative importance of a firm as a customer or as a supplier in the supply-chain network. The Kleinberg centralities of customers and suppliers capture their relative bargaining power and their ability to switch to other supply-chain partners.

At the industry level, we use the Herfindahl–Hirschman index (*HHI*) to measure concentration. The *HHI* is defined as the sum of squared market shares of individual firms in the corresponding industry. In addition, to measure if environmental performance is financially relevant for the firm, we use the materiality matrix from the SASB.[8] In the context of the environment, SASB evaluates whether each of six factors—GHG emissions, Air quality, energy management, water & wastewater management, waste & hazardous materials management, and ecological impacts—is material for firms in a given industry.

Table 1 summarizes the main variables considered across the three types of relationships. We report the mean, standard deviation, and selected percentiles of all variables for the focal firms, as well as the number of (focal) firm years for which we have data on a given variable. We drop the observations with negative equity values and Winsorize all company-level control variables at the first and 99th percentiles. Focusing on environmental performance, for competitors (Panel A), we identify 33,182 focal-firm years, for which we observe *EnvScr*. Not all firms scored by Asset4 report CO2 emissions, so the sample for *CO2toRev* is smaller, amounting to 17,109 competitor-years. The pattern is similar for suppliers (Panel B of Table 1) with 24,722 and 13,249 firm years for *EnvScr* and *CO2toRev,* respectively, as well as for customers (Panel C), where the respective

[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" (SASB, 2020).

numbers are 27,576 and 15,229. From a network perspective, we identify 234,572 (140,229) competitor-pair years, where the related firm also has data on *EnvScr* (*CO2toRev*). Taking customers as focal, that number is 168,441 (119,135), and when focal firm is supplier, it is 176,144 (100,119). The number of observations outside the reported relationship periods (the "inactive" sample) is almost double the "active" sample for competitors and almost triple for customers and suppliers. This gives us enough power to estimate differences between the "active" and "inactive" years of firm relationships.

Comparing mean values in Columns (1) and (8) of Table 1, it appears that *EnvScr* is slightly higher and *CO2toRev* lower in the "active" sample. Importantly though, the "active" and "inactive" samples appear very similar on a range of firm and country characteristics defined as control variables. Thus, the apparent differences in environmental performance are not due to systematic differences in the type of firms or countries we observe. To confirm that these differences are also not due to general trends in environmental performance at, for example, the industry level, we adjust for year-industry effects in our analysis.

## 4. Baseline Analysis

In this section, we present our baseline analysis investigating the propagation of environmental performance among firms related to each other through the supply chain or by being competitors in the same product market. The aim is to provide an overall view of the importance of firms' network connections for the propagation of environmental performance. We estimate the panel-data regression model

$$EnvPerf_{f,t} = \alpha_{fr} + \delta_t + \beta\ EnvPerf_{r,t-1} + \gamma_f' X_{f,t-1} + \gamma_r' X_{r,t-1} + \varepsilon_{fr,t}, \tag{1}$$

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

where $EnvPerf_{f,t}$ and $EnvPerf_{r,t}$ are measures of environmental performance of the focal firm *f* and related firm *r*, respectively, at time *t*, while $\beta$ is the parameter of interest and shows the effect of the related firm's *EnvPerf* at time *t*–1 on the focal firm's *EnvPerf* at time *t*. $X_{f,t}$ and $X_{r,t}$ are vectors of focal- and related-firm control variables, respectively, and $\gamma_f$ and $\gamma_r$ are the related parameter vectors. $\alpha_{fr}$ is the firm-pair fixed-effect parameter, and $\delta_t$ is the year fixed-effect parameter. $\varepsilon_{fr,t}$ is the residual term at time *t* of the regression for focal firm *f* facing related firm *r*. *N* and *M* are the numbers of focal and related firms, respectively, used in the estimation. Because we estimate the model for different types of relationships, *N* and *M* can vary depending on the type of the relationship under consideration.

We take several steps to mitigate concerns that the propagation effect could be driven by common trends or characteristics. First, we control for characteristics of both the focal and related firm and use lagged values of all the control variables. We use firm-pair fixed effects instead of (focal) firm fixed effects to simultaneously capture time-invariant unobservable characteristics at the firm, industry, and country levels that affect environmental performance. In our most rigorous specification, we replace year fixed effects with a year-industry adjustment on each variable by subtracting the mean value for a given industry in a given year. This procedure accounts for common trends that affect all firms in a given industry. We believe adjusting in this way is superior to including year-industry fixed effects because it allows us to subtract the relevant mean for both focal and related firms even if they belong to different industries.

Table 2 shows the estimation results for the two measures of environmental performance we use: CO2 emissions scaled by revenue (*CO2toRev,* Panel A), which is our primary measure, and the

Environmental Pillar Score assigned by Asset4 (*EnvScr,* Panel B). Aggregate ESG scores have been criticized for being a "black box" and also quite inconsistent across different providers (Berg et al., 2022).[9] Concerns have also arisen that such aggregate measures of environmental performance may be inflated due to "greenwashing." Thus, from the perspective of tackling climate change, our main interest is in the results for *CO2toRev*.[10] However, we include *EnvScr* in our analysis for two reasons. First, this choice helps us relate our results to earlier studies such as Schiller (2018). Second, it also helps us compare the propagation of environmental scores, which include "soft" declarative measures, to the propagation of carbon intensity, a "hard" objective outcome.

We expect to find positive coefficients on the related firms' *CO2toRev* (*EnvScr*), meaning that focal firms are proportionally affected by the actions of their rivals and partners. By contrast, we expect *CO2toRev* and *EnvScr* to load on our control variables with opposite signs, because improvements in environmental performance entail decreases in carbon intensity and increases in environmental scores. We expect *Size*, *Tobin's q, ROA* and *Sales turnover* to negatively affect *CO2toRev* and to positively affect *EnvScr*. Larger firms face greater political and social attention and their environmental performance may be subject to a higher degree of scrutiny. In addition, larger firms should be better equipped to make use of economies of scale to, for example, implement new emission-reduction technologies (see, e.g., Artiach et al., 2010). *Tobin's q* captures companies' future growth opportunities and is also considered a proxy for management's ability to generate value from a unit of underlying assets (see, e.g., Buchanan et al., 2018), both of which could enhance the environmental performance of high-*q* firms. More profitable companies (higher

[9] Asset4 has additionally faced criticism for "rewriting history" after retroactively changing a large portion of its scores following a methodology change in 2019.

[10] It is important to point out that CO2 emissions reported in Asset4 were not affected by the "rewriting history" problem and are also consistent with values reported by other providers, such as Trucost.

*ROA*) have more funds to improve their environmental performance, while companies with low profitability need to reduce their costs to be able to provide returns to their investors (see, e.g., Artiach et al., 2010). *Sales turnover* measures companies' relative efficiency in an industry and is expected to have positive impact on environmental performance. On the other hand, we expect *Leverage* to affect *CO2toRev* positively and *EnvScr* negatively because highly leveraged firms may face limitations for financing new technologies required to enhance environmental performance. For country-level controls, we expect *GDPperCap* to be negatively related to *CO2toRev* and positively related to *EnvScr,* since richer countries, similarly to more profitable companies, have more resources to invest in environmental performance. For *CO2toGDP*, we expect a positive link with *CO2toRev,* since the overall carbon intensity of a country's economy should also have a bearing on the carbon intensity of companies headquartered there. Consequently, we expect a negative relationship between *CO2toGDP* and *EnvScr*.

The first column of Table 2, Panel A shows that the coefficient on *CO2toRev-R* (the *CO2toRev* of the related company) is positive and highly significant if the related firm is a competitor. The second column shows that the coefficient is almost unchanged if we replace year-fixed effects with a year-industry adjustment of each variable. This indicates that propagation between competitors in terms of carbon performance is not driven by industry-specific trends but rather by competitive effects or pair-specific knowledge spillover. A decrease in a competitor's *CO2toRev* by one standard deviation implies a decrease in the *CO2toRev* of the focal company by close to 3.5% of a standard deviation (the standard deviation of *CO2toRev* among competitors is 945 ton/million USD), which amounts to a reduction of emission with around 8%, relative to the sample mean (418 ton/million USD). Among the firm-level control variables, the coefficients of *Sales turnover*, *Tobin's q*, and *ROA* are significant. The signs of the coefficients are in line with the expectations and show that profitable, growing firms with higher sales turnover have higher environmental performance. Additionally, the coefficient on *CO2toGDP* is significant and positive, which indicates that firm-level performance in carbon intensity is partly driven by general developments at the country level.

Next, we consider customers as related firms. The third column of Table 2, Panel A shows that, with year fixed effects the coefficient on *CO2toRev-R* is positive and significant but also smaller than that obtained when considering competitors as related firms. The fourth column shows that, with year-industry adjustment, the estimated customer effect is almost zero and insignificant. This indicates that the apparent customer effect on suppliers in terms of carbon performance can in fact be explained by common industry trends rather than propagation due to reputational pressure or pair-specific technological spillover. The last two columns of Table 2, Panel A suggest the same is true for the opposite effect from suppliers to customers; it is also driven by common industry trends.

Next, we analyze transmission of aggregate environmental scores. We report the estimation results in Table 2, Panel B. If the related firm is a competitor, the coefficient on *EnvScr-R* (the *EnvScr* of the related company) is positive and highly significant under both types of trend adjustment, as with the result for *CO2toRev*. To illustrate the economic magnitude, recall that *EnvScr* is essentially a percentile ranking bounded by 0 and 100. Thus, with the coefficient on *EnvScr* being 0.024, an increase in a competitor's *EnvScr* from the 25th to the 75th percentile implies an increase in the focal firm's ranking by 1.2 percentiles.

If the related firm is a customer, the coefficient on *EnvScr-R* is positive and significant with both types of trend adjustment, which indicates the presence of customer-induced reputational effect or pair-specific spillover. This result is in line with previous studies (e.g., Schiller, 2018; Dai et al.,

2021) that find a positive customer effect on aggregate environmental performance.[11] Why do customers influence suppliers' aggregate environmental performance but not their carbon intensity? A possible explanation is the existence of technological barriers to reduce carbon intensity. Facing pressure from the customers, firms may find it more technologically feasible to improve environmental performance in other areas than reducing carbon intensity. Another possible scenario is that it is easier to improve "declarative" outcomes, like policies and targets, than "real" outcomes like actual emissions reduction, which raises concerns of greenwashing.

Finally, if the related firm is a supplier, the coefficient of *EnvScr-R* is insignificant and almost zero with both types of industry adjustment, which indicates that suppliers do not affect the environmental scores of their customers.

Overall, our results suggest important differences between propagation of carbon intensity and environmental score. Furthermore, a comparison across competitor and customer–supplier relationships reveals that propagation among competitors is stronger than along the supply chain. This confirms our expectation laid out in Section 2: Competitor effects are first order because actions by competitors directly change the relative standing of focal firms, providing a strong incentive for them to act as well.

# 5. Identifying Causal Effects

Although we control for common observable characteristics and rigorously adjust for year-industry variation, there can still be concerns for endogeneity when we try to establish a causal effect from active corporate relationships on environmental performance propagation. One possible issue is

[11] Although Schiller (2018) uses a constructed index instead of the ASSET4 *EnvScr,* our results are comparable as the two measures, as shown by Schiller (2018), are highly correlated.

selection bias related to environmental performance. To decrease reputational risk along the supply chain, firms may tend to buy from suppliers or sell to customers with similar environmental performance to their own. As a result, firms will form supply-chain relationships with other firms having similar environmental performance. Such assortative matching of supply-chain partners can confound propagation effects along the supply chain. In comparison, assortative matching may be less of a concern for identifying competitor effects, since firms generally do not actively select competitors. Furthermore, it could be possible that firms respond to environmental action of potential competitors, and potential customers and suppliers, to gain competitive advantage and bargaining power. The problem of selection bias is expected to be partially, but not entirely, addressed by the pair fixed effect in the model, as the selective behavior may change over time. In addition, since *CO2toRev* and *EnvScr* tend to be persistent over time, the estimated effects of related firms may be biased if the focal firm affects its related firms, a case of reverse causality. We use two approaches to deal with such endogeneity concerns.

First, to address selection, we compare the sample of "active" firm-pair years used in the baseline analysis to a placebo sample of "inactive" firm-pair years. Firm-pair year *ijt* enters the "inactive" sample if firm *i* and firm *j* are not related at *t* but are related at some other time in the sample period between 2004 and 2019. In the absence (presence) of selection bias, we should expect the effect of *EnvPerf* from related firms to be zero (positive) in the inactive sample, and if the estimated effect of related firms is channeled mainly by active relationships between the firms, it should be stronger in the active sample than in the inactive sample. To make the comparison, we pool the two samples and define two dummy variables identifying observations belonging to each sample. The $Active$ dummy takes value one if firm-pair year $ijt$ belongs to the active sample and value zero if it belongs to the inactive sample. The $Inactive$ dummy is defined in reverse. Then, we augment the baseline regression in equation (1) by interacting $EnvPerf_{r,t-1}$ with the two dummy variables. The augmented regression is

$$EnvPerf_{f,t} = \alpha_{fr} + \beta_1\, EnvPerf_{r,t-1} \times Active + \beta_2\, EnvPerf_{r,t-1} \times \text{In}active \\ + \rho\, Active + \gamma_f' X_{f,t-1} + \gamma_r' X_{r,t-1} + \varepsilon_{f,t}. \tag{2}$$

The coefficient $\beta_1$ implies the effect of related firms in the active sample, and $\beta_2$ the effect in the inactive sample. We interact $EnvPerf_{r,t-1}$ with both dummies rather than with $Active$ only, because we are interested in the effects in both samples. To investigate whether the effect is more pronounced in the active sample, we conduct a *t*-test on the statistical significance of the difference between $\beta_1$ and $\beta_2$. We include the same control variables as in the baseline regression and adjust for year-industry variation.

We report the estimation results of the augmented regression in Table 3. We do the identification analysis of the competitor effect in terms of *CO2toRev* and *EnvScr* and customer-to-supplier effect in terms of *EnvScr* only, since these effects were statistically significant in the analysis of Section 4. The first column shows the result for the propagation of *CO2toRev* among competitors. The coefficient for *CO2toRev-R*×*Active* is positive and significant whereas the coefficient for *CO2toRev-R*×*Inactive* is insignificant. Moreover, the *t*-test on the difference between the coefficients returns a *p*-value of 0.05. The fact that propagation is significant and significantly stronger in the active sample supports the causal interpretation that firms change their carbon intensity in response to similar changes by their active competitors. In contrast, we do not find evidence for stronger propagation of *EnvScr* among active competitors. The coefficients on both interaction variables in the second column are positive and significant, indicating that firm pairs comove in terms of *EnvScr* during both inactive and active periods. The difference between the coefficients is insignificant with *p*-value 0.80. Thus, the significant competitor effect of *EnvScr* shown in Table 2 is not channeled by active competitor relationships.

Comparing the coefficients on *EnvPerf-R*×*Inactive* in the first two columns of Table 3, we see that firms keep up with *EnvScr* rather than *CO2Rev* of their potential competitors. A possible explanation is that *EnvScr* captures more declarative aspect of environmental performance while *CO2Rev* is more concrete. Because reducing carbon intensity requires more effort, firms only react to *CO2Rev* of active competitors rather than potential competitors. In contrast, it is relatively easy for firms to respond to *EnvScr* of potential competitors. Thus, *EnvScr* seems to be used as a tool when firms face potential competitive threat. These findings indicate that *EnvScr* may be indeed subject to "greenwashing" and that *CO2Rev* is a more reliable measure of firms' environmental performance.

We report the result for customer-to-supplier propagation in *EnvScr* in the third column in Table 3. The finding is similar to that of competitor propagation in *EnvScr*. The coefficients on both interaction variables are positive and significant, and the difference between them is not significant, indicating that the customer effect of *EnvScr* shown in Table 2 is not driven by active supply-chain relationships between the firms.

Second, to address the possibility of reverse causality, we adopt an approach similar to the quasi-natural experiment of Schiller (2018), which exploits the staggered introduction of environmental regulations in different countries. While companies can, to some degree, influence domestic regulatory changes through, for example, lobbying activities, such changes are arguably exogenous from the perspective of foreign companies. Therefore, we use the introduction of environmental regulations in the (foreign) country of related company headquarters as quasi-exogenous shocks to the focal firm. We hand-collect data on country-level regulations from

"*Carrots & Sticks*" reports, a series of regular stocktakes of sustainability disclosure requirements worldwide. The database was launched by the UN Environment Programme together with KPMG International in 2006, and it builds on KPMG's regular global survey of corporate sustainability reporting. Our regulation variable indicates the introduction of mandatory and voluntary instruments that either require or encourage organizations to report sustainability-related information each year.

We estimate the following difference-in-differences regression:

$$EnvPerf_{f,t} = \alpha_{fr} + \lambda\, Regulation_{r,t} + \gamma_f' X_{f,t-1} + \gamma_r' X_{r,t-1} + \varepsilon_{f,t}, \tag{3}$$

where $Regulation_{r,t}$ is a dummy variable that takes value zero at the beginning of the sample and one going forward once an environmental regulation has come into effect in the country of the related company *r*. Thus, the treated (control) sample consists of international firm-pair years in which the country of the related company has (has not) introduced an environmental regulation. The coefficient $\lambda$ reflects the difference-in-differences effect of environmental regulation in the countries of related companies on foreign focal firms. As in the baseline analysis in Section 4, we apply year-industry adjustment and control for pair fixed effects, characteristics of the focal and related companies, and *GDPperCap* and *CO2toGDP* of the countries of the focal and related company. We estimate the model both with and without controlling for regulation changes in the focal company country, which are captured with a dummy variable as with $Regulation_{r,t}$.

We report the coefficients of the difference-in-differences effect in Panel A of Table 4. The first two columns show that the coefficient of regulation changes in foreign competitor countries is negative and statistically significant when using *CO2toRev* to measure environmental performance. The coefficient is robust to whether we control for regulation changes in the focal company country. This result points to a causal effect of foreign competitors on the focal company in terms of carbon intensity. As Column (2) shows, introduction of environmental regulation in the foreign competitor countries implies a reduction in the focal company's *CO2toRev* by around 14 ton/million USD, a reduction of around 3.4%, relative to the sample mean (418 ton/million USD). In contrast, as Columns (3) and (4) show, regulation changes in foreign competitor countries do not appear to influence the focal company's *EnvScr*. Similarly, Columns (5) and (6) show insignificant effects of regulation changes in foreign customer countries. This result seems to contradict Schiller (2018), who finds a significant effect of foreign-customer country regulations. An explanation for the deviation of our result from Schiller (2018) may be that we control for *CO2toGDP* while Schiller (2018) does not. *CO2toGDP* may capture part of the effect from regulation changes. In fact, if we do not control for *CO2toGDP*, the effect of foreign-customer country regulation on the focal company's *EnvScr* is positive and statistically significant (see Column (7) of Panel A). In addition, we find focal firms' environmental performance to be significantly driven by regulation changes in their own country in all cases.

These identification approaches consistently suggest that propagation in terms of *CO2toRev* among competitors is causal and is related to the situation when peers actively compete in the market. However, in other cases (*EnvScr* among competitors, between customers and suppliers in general), we cannot ascertain such causal effect.

Having established the baseline identification, it is interesting to see whether the effect of regulations depends on the cross-country differences in environmental attitudes and in the level of economic development. We examine these differences for competitor propagation only, since it is the only one remaining significant in Table 4, Panel A. If the focal company is headquartered in a country with relatively higher proenvironmental attitudes, the effect of foreign-competitor country regulations should be stronger, because the focal company faces greater scrutiny from its stakeholders at home and thus is more likely to improve its own environmental performance. By contrast, the role of economic development is ambiguous. On one hand, focal companies from countries with relatively higher GDP per capita have more resources to improve environmental performance. Therefore, they may be more likely to react to regulation changes in related-company countries. On the other hand, countries with higher levels of economic development may have higher environmental standards and practices already.[12] Therefore, one may also expect the effect of the foreign-country regulation to be stronger if the focal company is headquartered in a country with relatively lower level of economic development than the country of the related company, as the companies in highly developed countries might already satisfy the regulation in the related company's country.

We first split the sample based on the relative proenvironmental attitude of the focal and related firm's country. To identify proenvironment countries, we draw on the World Values Survey, specifically the responses to the question about "Protecting environment vs. Economic growth."[13] We construct a dummy variable $1_{Yes}$ that takes value one (zero) if the percentage of proenvironment answers is higher (lower) in the focal firm's country than in the related firm's country, and a dummy variable $1_{No}$ if the opposite is true.

Likewise, we split the sample based on the level of economic development, which we capture with GDP per capita. Specifically, we construct a dummy variable $1_{Yes}$ ($1_{No}$), which takes the value of

[12] In fact, Schiller (2018) argues that GDP per capita is a proxy for environmental standard and practices.

[13] Question number Q111 in Wave 7: Here are two statements people sometimes make when discussing the environment and economic growth. Which of them comes closer to your own point of view? (*Read out and code one answer*): 1. Protecting the environment should be given priority, even if it causes slower economic growth and some loss of jobs. 2. Economic growth and creating jobs should be the top priority, even if the environment suffers to some extent. 3. Other answer (*code if volunteered only!*).

one if the focal firm is headquartered in a country with lower (higher) GDP per capita than the country of its related-firm headquarters. We augment equation (1) by interacting $Regulation_{r,t}$ with the dummy variables.

We report the results in Panel B of Table 4. The columns under *Proenvironment* show the coefficients from the regression where focal firms are split based on environmental attitudes in its country of headquarters. The specification in Column (1) does not control for regulatory changes in the focal company country (*Regulation-F*), whereas the specification in Column (2) does. We can see that, in both specifications, the coefficient for *Regulation-R*$\times 1_{Yes}$ is negative and statistically significant while the coefficient for *Regulation-R*$\times 1_{No}$ is not significant. Also, the *t*-tests on the differences between the coefficients are highly statistically significant. Thus, regulation changes in the foreign country affect carbon intensity of the focal firm only if its country of headquarters has higher proenvironmental attitudes. Columns (3) and (4) under the heading of *Lower GDP* show coefficients from the regression where the dummy variables are defined based on GDP per capita. The coefficients for both interaction variables are negative and significant. The *t*-test on the difference between the two coefficients returns a *p*-value of 0.51, indicating that the difference is not statistically significant. This is in line with our expectation of an ambiguous role of economic development of the focal-company country relative to that of the competitor-company country.

# 6. Further Analysis of Competitor effects

In this section we perform a deeper analysis of the propagation of environmental performance among related firms. Our results so far show that there is no propagation of carbon performance from customers to suppliers and vice versa once we control for industry trends. For the transmission of environmental scores, we find a significant effect, but the identification analysis in Section 5 shows that this result is likely due to confounding factors. Therefore, to save space, we focus only on the propagation of our main measure of environmental performance, carbon intensity, among competitors.[14] In Section 6.1, we explore the channels of propagation by analyzing how the propagation depends on industry concentration, firm strength, and environmental materiality. In Section 6.2, we investigate if the propagation depends on the level and the direction of the changes in carbon intensity. Finally, in Section 6.3, we look at the role of geographical proximity among competitors and use a more declarative measure of environmental performance.

### 6.1 Channels of propagation

In this section, we explore in depth two channels of environmental-performance propagation among competing firms: competitive effect and technological spillover.

#### *6.1.1 Industry concentration and competitive effects*

In a perfectly competitive market, the competitive effect should be negligible as the exit or entrance of a firm should not affect the market shares of the other firms. With an increase in industry concentration, the competitive effect should become stronger as each firm may be more affected by the actions of its competitors (see Lang and Stulz, 1992).[15] Moreover, firms in a highly concentrated industry are more subject to scrutiny, which may force them to enhance their

[14] We have also estimated all the regression models in coming sections for customer and supplier effects and the results are in general insignificant throughout different specifications.

[15] According to Lang and Stulz (1992), the importance of the competitive effect is inversely related to the degree of competition, since in a perfectly competitive industry, firms cannot earn rents from an increase in demand in case of the bankruptcy of a rival firm. In more competitive industries, however, the increase in demand increases the present value of the rents because the increase in demand may result in a higher product price.

environmental impacts if rivals do so. Hence, we expect stronger propagation from competitors in highly concentrated industries.

We first investigate if the propagation depends on the degree of competition. We use the HHI to capture the overall level of concentration or competition in the product market and define an indicator ($1_{Yes}$) that takes value one for firms in industries with an above-median HHI and an indicator ($1_{No}$) that takes the value of one if the opposite is true. The first column of Table 5 shows the results. The interaction terms of *CO2toRev* with the indicators show that the propagation among competitors is significant for both high-HHI and low-HHI industries, but it is much stronger for the firms in the high-HHI industries. The difference between the coefficients is statistically significant (see the *p*-values in the table). This supports our hypothesis that when firms compete with fewer rivals in the product market, they face more intense competitive threat if their environmental performance lags behind.

*6.1.2 Firm strength and competitive effect*

A firm's strength determines its capability of developing a competitive advantage. We consider two kinds of firm strength: market power and bargaining power in the supply chain. A focal firm with larger market power than its competitor should be more resilient to competition and thus less likely to react to the competitor's environmental action. Moreover, firms with large bargaining power over their supply-chain partners may receive less pressure from the partners to catch up with the environmental standards of their competitors. Therefore, we hypothesize that the competitive effect is weaker for focal firms that have greater bargaining power than their competitors. Furthermore, bargaining power as supplier may not yield the same level of resilience to competition as bargaining power as customer. Schiller (2018) and Dai et al. (2021) find unidirectional effects from customer to supplier in terms of environmental performance. Therefore, we expect customer bargaining power to be more important than supplier bargaining power when firms face competitive threats.

We first use the firms' *MktShr* relative to their rivals to capture firms' market power. However, as the market share of a firm may itself be affected by its environmental performance, there could be reverse causality between changes in the environmental performance and the market share. We, therefore, also use the relative *Size* of the firms to measure market power.

For both of these variables, we define an indicator ($1_{Yes}$) that takes value one when a focal firm has a higher value on that variable than its rival, and an indicator ($1_{No}$) that takes the value of one if the opposite is true. As with the HHI, we extend the baseline model by interacting *CO2toRev* of the related firms with these indicators. Columns (2) and (3) of Table 5 illustrate the results. As expected, we find weaker propagation of *CO2toRev* to firms that have higher market share and are larger in size. The differences between the interaction terms are all significant at the 5% level for the market-share variable but not for the size variable.

To measure overall bargaining power in the supply chain, we use the number of supply-chain links. We define an indicator ($1_{Yes}$) which takes the value of one when a focal firm has a larger number of supply-chain links than its rival, and an indicator ($1_{No}$) which takes the value of one if the opposite is true. We interact the *CO2toRev* of the related firms with these indicators. Column (4) of Table 5 illustrates the results. Supporting our hypothesis, the propagation of *CO2toRev* to firms with more links is weaker than to their rivals and the difference between the coefficients on the interaction terms is significant at the 5% level. Therefore, we may conclude that firms with higher bargaining power drive environmental performance and those with lower bargaining power generally follow.

Furthermore, we consider the roles of customer bargaining power and supplier bargaining power separately. As motivated in Section 2, we expect customer bargaining power to be more important than supplier bargaining power when firms face competition. As described in Section 3, we use centrality as customer (supplier) to measure customer (supplier) bargaining power. Column (5) of Table 5 shows that the degree of propagation does not vary with focal firms' supplier bargaining power, as the difference between the interaction terms is not statistically significant. As for customer bargaining power, Column (6) shows that the difference between the interaction terms is not statistically significant either, contrary to our expectation. The last three columns of Table 5 point to the particular importance of overall bargaining power for the competitive effect.

*6.1.3 Materiality and technological spillover*

Firms are more likely to innovate for the purpose of environmental protection if environmental issues are *material*: likely to impact their operational and financial performance. In addition, these firms may have greater incentive to learn innovative environmental technologies from their peers. Therefore, we hypothesize that propagation of environmental performance is stronger among competing firms for which environmental issues are material.

Based on the industry-level materiality matrix from the SASB, we define an indicator which takes the value of one if both focal and related firms belong to industries for which environmental issues are highly material, and an indicator which takes the value of one if both belong to industries for which environmental issues are not material. To ensure robustness, we use three different cutoff points to define high environmental materiality. Specifically, we consider materiality to be high if at least two, three or four of the six factors included by SASB in the Environment dimension are considered material for firms in a given industry.[16] We interact the indicators with *CO2toRev* of the related firms. Firm pairs are excluded from the sample if one of the firms is in the high materiality group and the other in the low group. Table 6 shows that the transmission of environmental performance between competitors is strongest when they belong to industries with high materiality and the effect increases with the materiality cutoff point.[17] The interaction terms' difference is statistically significant in all cases. These results support our hypothesis that the propagation of carbon performance among competitors is in part due to technological spillover.

### 6.2 Leaders pulling up or laggards dragging down?

In this Section, we investigate if the propagation depends on the level and direction of the changes in environmental performance. This is an important dimension, because what is needed for a successful transition to a sustainable economy is for improvements in environmental performance to propagate in the corporate network. However, the propagation effect we identified previously could, in principle, be symmetric: Related firms with high and increasing emission could be dragging the focal firms down in terms of environmental performance.

We start by dividing the sample based on the median value of the focal firms' lagged *CO2toRev*, into two groups, *Low* and *High,* and define an indicator $1_{yes}$ that takes value one for the firms that belong to the *High* group and another indicator $1_{No}$ which takes value one for firms in *Low* group. We expect the effect from the *CO2toRev* of the related firms to be larger if the focal firm has a high carbon intensity, since the focal firms do not feel pressure to improve their performance if

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[16] The six factors are GHG Emissions, Air Quality, Energy Management, Water & Wastewater Management, Waste & Hazardous Materials Management, and Ecological Impacts.

[17] We also estimate the model for consumer-facing industries as the group most likely to face widespread pressure on environmental issues in the form of, for example, boycotts. We consider four 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, but the results do not support our hypothesis. One explanation could be that the consumer-oriented industries have in general very low carbon intensity; the mean carbon intensity in these industries is equal to 57.33 ton/million USD, about one tenth of the mean carbon intensity of the other industries (537.41 ton/million USD).

they already perform well. The results, reported in Column (1) of Table 7, support our conjecture and show that the spillover among competitors is only significantly positive for focal firms with high initial *CO2toRev*.

Further, we check whether firms tend to adjust their environmental performance to that of the related firms mainly when the related firms improve their own environmental performance. Therefore, we divide the sample in two groups based on the sign of related firms' changes in *CO2toRev*, those that have a negative change (decrease) and those with a positive change (increase). The results in the Column (2) of Table 7 show some evidence that focal firms reduce *CO2toRev* more when their competitors also reduce their own carbon intensity. The size of the coefficient (0.0423) is about twice as large in case of a decrease in *CO2toRev* in comparison to the case of an increase in *CO2toRev* (0.0232), although the difference between the coefficients is not statistically significant. The positive and significant propagation effect in the case of an increase in *CO2toRev* might be explained by such factors as production requirements or cost management, rather than a deliberate decision to worsen environmental performance.

Overall, we find support for the theory that environmental performance propagates towards focal firms with poor initial records, good news for the transition to an overall greener economy.

### 6.3 Robustness and extensions

In this section, we conduct two sets of tests. First, we compare the propagation effect between rival firms headquartered in the same country and in different countries. Second, we examine the propagation effect for an alternative measure of environmental performance.

The motivation for considering geographical subsamples is twofold. Firstly, it seems plausible that the propagation effect would be stronger among proximate rivals, such as those headquartered in the same country. Secondly, such an analysis can provide additional evidence, to what is shown in Table 4, that the effect we find in the baseline model is not mainly driven by country-level processes. As can be seen when comparing Columns (1) and (2) of Table 8, the propagation effect for *CO2toRev* is roughly twice as strong among rival firms headquartered in the same country versus in different countries. However, the latter effect is also statistically highly significant. Thus, propagation among rival firms exists regardless of potential country-level processes, although they could explain some of the effect for *CO2toRev*. Finally, we find no appreciable difference when we stretch the geographic separation even more by requiring rival firms to be headquartered in different broad geographic regions.

For the second set of tests, we consider an additional measure of environmental performance, an indicator variable for whether the company has a policy to improve emission reduction (*Policy*), as judged by Asset4 analysts. The purpose of these tests is to see how the propagation effect found previously for a "hard" measure of a firm's approach to emissions, *CO2toRev*, compares to the propagation of a more declarative measure. We follow our previous strategy of first controlling for year fixed effects and subsequently replacing them with a stricter industry-year adjustment on company-level variables.

Columns (1) and (2) of Table 9 show the estimation results for the propagation of emission-reduction policies. The effect is significant in the presence of year-fixed effects (Column 1), but disappears once company-level variables are adjusted for their year-industry means (Column 2), suggesting that different industries adopt such policies at different points in time in contrast to genuine propagation among rival firms. We also examine whether the adoption of emission reduction policies by related firms affects actual carbon intensity of focal firms. Thus, in Columns (3) and (4), we estimate the propagation effect from *Policy* of related firm to *CO2toRev* of the focal firm. Again, we find the effect to be sensitive to the year-industry adjustment of variables, suggesting it does not represent genuine propagation. Overall, the analysis leads us to conclude that the propagation effect is not robust for declarative measures of environmental performance.

## 7. Conclusion

In this paper, we study the corporate-network channel for environmental-performance propagation. We consider three types of related firms: competitors, customers, and suppliers. To measure firms' environmental performance, we mainly use a concrete measure, firms' $CO_2$ emissions scaled by revenue. We also consider a more declarative measure, environmental score, which has been more widely studied in previous research. Our results indicate that firms' environmental performance positively correlates with the lagged environmental performance of all types of related firms. The magnitude of correlation with competitors is larger than correlations with customers and suppliers. However, positive correlation does not necessarily represent genuine propagation. For stricter identification, we adjust for industry trends of focal and related companies as well as conduct a quasi-natural experiment and a placebo analysis. We find genuine transmission among competitors in terms of carbon intensity. However, the positive correlations between competitors in environmental score and correlations between customers and suppliers in both environmental-performance measures appear to be due to confounding factors.

We explore two channels of carbon-intensity propagation among competitors: competitive pressure and technological spillover. We find the competitor effect to be greater for firms in more-concentrated industries and for firms with less market power or less bargaining power than competitors. Also, we find that financial materiality of environmental issues may incentivize technological spillover among competing firms, since the degree of propagation is greater if both the focal firm and the competitor operate in industries for which environmental issues are highly material.

Furthermore, we show that carbon-intensity reduction propagates towards focal firms with poor initial records. Transmission is stronger among firms headquartered in the same countries than among those headquartered in different countries. Also, unlike actual carbon intensity, competitors' policies for emissions reduction do not have genuine propagation effects on focal firms' policies or actual carbon intensity.

Overall, we conclude that peer pressure and spillover among competitors are the main drivers of carbon-intensity transmission. The competitor network may therefore spread government policies for reducing carbon intensity, which is a force for good in combating climate change. Our findings also suggest that it is more effective for policymakers to target industries with stronger competitive pressure and technological spillover as well as firms with large market power and bargaining power. Finally, our study points to the importance of distinguishing different measures of environmental performance in future research.

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**Table 1. Summary statistics of the variables**

The table reports the summary statistics of the main variables for the samples of active and inactive relationships, for focal firms as competitors (Panel A), suppliers (Panel B), and customers (Panel C). *EnvScr* is the company's environmental score and *CO2toRev* is the ratio of the company's total CO2-equivalent emissions to its total revenues in USD million. *Size* is the logarithm of total assets in USD million. *Sales turnover* is the ratio of total sales to total assets. *Leverage* is the ratio of total debt to the book value of total assets. *Tobin's q* is market-to-book equity ratio, and *ROA* is return on assets. *GDPperCap* and *CO2toGDP* are country-level variables. We drop the observations with negative equity values and Winsorize all company-level variables to 1% from both sides. The sample covers the period from 2004 to 2019.

**Panel A. Focal firms: Competitors**

| | Active Sample | | | | | | | Inactive Sample | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Median | St. dev. | 25% | 75% | #Firm year | #Pair year | Mean | Median | St. dev. | 25% | 75% | #Firm year | #Pair year |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
| *EnvScr* | 36.5533 | 35.0167 | 29.1168 | 7.1264 | 61.6278 | 33,182 | 234,572 | 34.3118 | 31.0068 | 28.5767 | 5.8773 | 58.3555 | 43,661 | 397,439 |
| *CO2toRev* | 417.9899 | 56.6134 | 945.0309 | 20.8075 | 326.3890 | 17,109 | 140,229 | 463.2046 | 63.4183 | 1026.3919 | 21.8991 | 358.2068 | 21,549 | 239,815 |
| *Size* | 22.2524 | 22.2523 | 1.5553 | 21.2606 | 23.2770 | 33,098 | 233,850 | 22.1483 | 22.1556 | 1.5389 | 21.1534 | 23.1621 | 43,458 | 396,115 |
| *Sales turnover* | 0.8395 | 0.7239 | 0.5719 | 0.4496 | 1.0704 | 33,067 | 233,801 | 0.8415 | 0.7230 | 0.5917 | 0.4286 | 1.0851 | 43,362 | 395,852 |
| *Leverage* | 0.2473 | 0.2368 | 0.1731 | 0.1141 | 0.3598 | 32,918 | 232,845 | 0.2457 | 0.2351 | 0.1737 | 0.1098 | 0.3586 | 43,232 | 394,372 |
| *Tobin's q* | 3.6874 | 2.3846 | 4.2814 | 1.4201 | 4.1220 | 31,191 | 221,711 | 3.5212 | 2.2901 | 4.0702 | 1.3805 | 3.9520 | 40,830 | 374,861 |
| *ROA* | 3.8497 | 4.6443 | 10.1986 | 1.4576 | 8.5397 | 32,943 | 233,068 | 4.2822 | 4.7548 | 9.8100 | 1.6296 | 8.6806 | 43,135 | 393,902 |
| *GDPperCap* | 10.6137 | 10.7825 | 0.6427 | 10.5840 | 10.9480 | 31,293 | 222,837 | 10.5580 | 10.7600 | 0.6957 | 10.5555 | 10.9163 | 41,000 | 375,481 |
| *CO2toGDP* | 0.2804 | 0.2675 | 0.1074 | 0.2153 | 0.3302 | 31,277 | 222,760 | 0.2903 | 0.2813 | 0.1161 | 0.2216 | 0.3397 | 40,973 | 375,421 |

**Table 1. Continued**

### Panel B. Focal firms: Suppliers

| | Active Sample | | | | | | | Inactive Sample | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Median | St. dev. | 25% | 75% | #Firm year | #Pair year | Mean | Median | St. dev. | 25% | 75% | #Firm year | #Pair year |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
| *EnvScr* | 38.1805 | 37.4319 | 29.2087 | 9.2609 | 63.4223 | 24,722 | 176,144 | 35.2100 | 32.6899 | 28.7042 | 6.6729 | 59.5701 | 40,156 | 512,091 |
| *CO2toRev* | 406.1647 | 54.9184 | 947.7143 | 20.7737 | 295.1532 | 13,249 | 100,119 | 438.5161 | 61.9549 | 993.4265 | 21.5673 | 329.8055 | 20,165 | 297,347 |
| *Size* | 22.3222 | 22.3092 | 1.6040 | 21.2696 | 23.4022 | 24,640 | 175,551 | 22.2166 | 22.2047 | 1.5246 | 21.2370 | 23.2124 | 39,994 | 509,936 |
| *Sales turnover* | 0.7984 | 0.6977 | 0.5347 | 0.4323 | 1.0298 | 24,605 | 175,478 | 0.8395 | 0.7319 | 0.5708 | 0.4416 | 1.0785 | 39,915 | 509,475 |
| *Leverage* | 0.2431 | 0.2319 | 0.1700 | 0.1131 | 0.3540 | 24,514 | 174,744 | 0.2438 | 0.2332 | 0.1702 | 0.1119 | 0.3542 | 39,794 | 508,056 |
| *Tobin's q* | 3.6469 | 2.3625 | 4.2506 | 1.4095 | 4.0402 | 23,330 | 166,532 | 3.4748 | 2.2672 | 4.0227 | 1.3677 | 3.8898 | 37,728 | 483,080 |
| *ROA* | 3.8500 | 4.5931 | 9.9263 | 1.4763 | 8.3373 | 24,532 | 174,978 | 4.5584 | 4.7777 | 9.1398 | 1.8097 | 8.6029 | 39,706 | 507,269 |
| *GDPperCap* | 10.5887 | 10.7869 | 0.6861 | 10.5824 | 10.9480 | 23,116 | 166,328 | 10.5364 | 10.7492 | 0.7235 | 10.5460 | 10.9163 | 37,528 | 484,331 |
| *CO2toGDP* | 0.2788 | 0.2675 | 0.1115 | 0.2117 | 0.3282 | 23,099 | 166,266 | 0.2878 | 0.2756 | 0.1182 | 0.2159 | 0.3391 | 37,506 | 484,248 |

### Panel C. Focal firms: Customers

| | Active Sample | | | | | | | Inactive Sample | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Median | St. dev. | 25% | 75% | #Firm year | #Pair year | Mean | Median | St. dev. | 25% | 75% | #Firm year | #Pair year |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
| *EnvScr* | 39.0786 | 39.0699 | 29.2248 | 10.3430 | 64.1954 | 27,576 | 168,441 | 34.7851 | 31.9597 | 28.5914 | 6.3141 | 58.8312 | 43,778 | 497,818 |
| *CO2toRev* | 466.4299 | 56.9052 | 1042.7088 | 20.9218 | 358.5235 | 15,229 | 119,135 | 468.6937 | 62.2732 | 1044.7907 | 21.3542 | 353.5675 | 21,863 | 347,361 |
| *Size* | 22.4733 | 22.5040 | 1.5615 | 21.4633 | 23.5144 | 27,494 | 168,041 | 22.2208 | 22.2150 | 1.5084 | 21.2614 | 23.2013 | 43,578 | 496,473 |
| *Sales turnover* | 0.8469 | 0.7103 | 0.5971 | 0.4319 | 1.0857 | 27,421 | 167,794 | 0.8559 | 0.7295 | 0.6025 | 0.4306 | 1.1016 | 43,429 | 495,232 |
| *Leverage* | 0.2540 | 0.2425 | 0.1728 | 0.1219 | 0.3666 | 27,343 | 167,364 | 0.2474 | 0.2368 | 0.1732 | 0.1124 | 0.3600 | 43,359 | 495,128 |
| Tobin's *q* | 3.5872 | 2.2735 | 4.2394 | 1.3697 | 3.9689 | 26,005 | 161,087 | 3.5167 | 2.2639 | 4.1162 | 1.3664 | 3.9213 | 41,066 | 474,180 |
| *ROA* | 3.9966 | 4.5443 | 9.6795 | 1.5792 | 8.3265 | 27,359 | 167,537 | 4.6248 | 4.7772 | 9.2408 | 1.7903 | 8.7042 | 43,260 | 494,219 |
| *GDPperCap* | 10.5372 | 10.7785 | 0.7472 | 10.5555 | 10.9480 | 25,751 | 158,216 | 10.5138 | 10.7429 | 0.7527 | 10.5273 | 10.9163 | 40,880 | 468,655 |
| *CO2toGDP* | 0.2824 | 0.2675 | 0.1148 | 0.2111 | 0.3315 | 25,736 | 158,178 | 0.2903 | 0.2813 | 0.1205 | 0.2159 | 0.3397 | 40,857 | 468,589 |

**Table 2: Estimation results for the baseline model across different relationships**

The table reports the results of the firm-pair fixed-effect estimation of the regression model with the focal companies' environmental performance as the dependent variable and one-year-lagged environmental performance (*CO2toRev-R* and *EnvScr-R*) of the companies related to the focal company as the independent variable. We use *CO2toRev* in Panel A and *EnvScr* in Panel B to measure environmental performance. The model is estimated for the effect from competitors, customers, and suppliers. In Specification (1), we use year dummy; in Specification (2), we use year-industry adjusted variables for company variables. The model also includes the lagged values of control variables for both focal and related companies: the logarithm of total assets (*Size*), the ratio of total sales to total assets (*Sales turnover*), the ratio of total debt to the book value of total assets (*Leverage*), the market-to-book equity ratio (*Tobin's q*), and the return on assets (*ROA*), as well as country variables *GDPperCap* and *CO2toGDP*. The data cover the period from 2004 to 2019. The standard errors shown within parentheses are clustered at the firm-pair level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

**Panel A. *CO2toRev***

| | Competitor effect | | Customer effect | | Supplier effect | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *CO2toRev-R* | 0.0389*** | 0.0350*** | 0.0150** | −0.0069 | 0.0210*** | 0.0015 |
| | (0.0083) | (0.0075) | (0.0066) | (0.0069) | (0.0078) | (0.0081) |
| *Size* | −4.3871 | 3.3261 | −42.1460*** | −11.0415*** | −56.4390*** | 10.1350* |
| | (12.2309) | (6.1028) | (6.5270) | (4.1885) | (10.9008) | (5.5339) |
| *Sales turnover* | −22.9871** | −4.4221 | −46.6388*** | −37.5135*** | −53.7988*** | 37.4061** |
| | (9.6848) | (9.6186) | (7.1255) | (9.4782) | (16.3524) | (17.5374) |
| *Leverage* | −57.1461 | −33.2519 | 104.3820*** | 95.8973*** | 18.7726 | 59.7860* |
| | (39.4459) | (35.8666) | (24.4047) | (24.6002) | (30.6965) | (35.4519) |
| *Tobin's q* | −0.9637** | −0.5007* | −1.8712*** | −0.2019 | −1.7073*** | −0.1836 |
| | (0.3950) | (0.3020) | (0.2825) | (0.2797) | (0.3850) | (0.3870) |
| *ROA* | −2.4487*** | −0.9498** | −0.7111*** | 0.3432 | −2.7154*** | −0.4419 |
| | (0.4081) | (0.3780) | (0.2420) | (0.3002) | (0.3653) | (0.3696) |
| *GDPperCap* | 1.1866 | 11.7474 | −2.2570 | −23.4840 | −22.5616 | −20.2567 |
| | (20.9149) | (19.4966) | (20.4634) | (23.0170) | (20.1157) | (20.0864) |
| *CO2toGDP* | 348.8793** | 249.0978** | 249.7184 | 208.0645* | −82.0025 | 89.2334 |
| | (138.8982) | (97.1715) | (163.3211) | (113.4604) | (184.1602) | (127.1314) |
| $R^2$ | 0.9633 | 0.9138 | 0.9753 | 0.9320 | 0.9758 | 0.9437 |
| Observations | 67,437 | 65,347 | 47,382 | 45,987 | 46,028 | 44,738 |
| Pair fixed effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Year fixed effect | Yes | No | Yes | No | Yes | No |
| Year-Ind. adjusted | No | Yes | No | Yes | No | Yes |
| Related firm control | Yes | Yes | Yes | Yes | Yes | Yes |

## Panel B. Environmental score (EnvScr)

| | Competitor effect | | Customer effect | | Supplier effect | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *EnvScr-R* | 0.0322*** | 0.0240*** | 0.0186*** | 0.0165*** | −0.0014 | 0.0024 |
| | (0.0051) | (0.0051) | (0.0062) | (0.0061) | (0.0055) | (0.0055) |
| *Size* | 4.7835*** | 9.0679*** | 3.5876*** | 9.0072*** | 4.7150*** | 8.3604*** |
| | (0.2604) | (0.1719) | (0.3340) | (0.2157) | (0.3384) | (0.2070) |
| *Sales turnover* | 3.2690*** | 5.1351*** | 2.6460*** | 5.7421*** | 1.5807*** | 3.4631*** |
| | (0.3517) | (0.3363) | (0.4038) | (0.3985) | (0.3604) | (0.3673) |
| *Leverage* | −0.0443 | −2.3884*** | 1.4724 | −3.2203*** | 1.1068 | 0.1350 |
| | (0.7410) | (0.7302) | (0.9311) | (0.9325) | (0.9196) | (0.9618) |
| Tobin's *q* | −0.0129 | 0.0686*** | −0.1826*** | −0.0160 | 0.0278 | 0.1039*** |
| | (0.0180) | (0.0182) | (0.0203) | (0.0216) | (0.0214) | (0.0247) |
| *ROA* | 0.0347*** | 0.0139** | 0.0262*** | 0.0129 | 0.0394*** | 0.0440*** |
| | (0.0063) | (0.0068) | (0.0084) | (0.0091) | (0.0098) | (0.0104) |
| *GDPperCap* | 2.0683*** | 2.0433*** | 6.5838*** | 6.2180*** | 3.0875*** | 3.0038*** |
| | (0.6947) | (0.6323) | (0.8618) | (0.7985) | (0.7593) | (0.6977) |
| *CO2toGDP* | −42.0278*** | −45.2704*** | 6.2685 | −25.1011*** | −3.5563 | −9.1615* |
| | (5.0735) | (4.2047) | (6.4386) | (4.9961) | (5.3068) | (4.8913) |
| $R^2$ | 0.9315 | 0.9121 | 0.9365 | 0.9194 | 0.9455 | 0.9239 |
| Observations | 169,875 | 164,284 | 116,077 | 112,443 | 111,497 | 108,093 |
| Pair fixed effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Year fixed effect | Yes | No | Yes | No | Yes | No |
| Year-Ind. adjusted | No | Yes | No | Yes | No | Yes |
| Related firm control | Yes | Yes | Yes | Yes | Yes | Yes |

**Table 3. Transmission in active periods versus inactive periods**

The table reports the results of the firm-pair fixed-effect estimation of the regression model with the focal companies' environmental performance, measured by *CO2toRev* and *EnvScr*, as the dependent variable and one-year lagged corresponding environmental performance of the companies related to the focal company as the independent variable (*EnvPerf-R*). The estimation is based on the sample including inactive relationships: the periods before and after the dates of the firms' recorded relationships. *Active (Inactive)* is an indicator that takes value one (zero) for the period of reported relationships of each pair and zero (one) otherwise. The *p*-value is for the test of the hypothesis that the coefficients of the interaction terms with *Active* (A) and *Inactive* (B) are equal. The model is estimated for the effect from competitors and customers. The model also includes the lagged values of control variables for both focal and related companies: the logarithm of total assets (*Size*), the ratio of total sales to total assets (*Sales turnover*), the ratio of total debt to the book value of total assets (*Leverage*), the market-to-book equity ratio (*Tobin's q*), and the return on assets (*ROA*), as well as country variables *GDPperCap* and *CO2toGDP*. All the company variables are year-industry adjusted. The data cover the period from 2004 to 2019. The standard errors shown in parentheses are clustered at the firm-pair level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

| | **Competitor effect** | | **Customer effect** |
|---|---|---|---|
| | **CO2 emissions** | **EnvScr** | **EnvScr** |
| *Active dummy* | 72.8056 | 2.614** | 5.4263*** |
| | (52.7745) | (1.0252) | (0.9476) |
| A: *EnvPerf-R × Active* | 0.0139** | 0.0210*** | 0.0171*** |
| | (0.0059) | (0.0035) | (0.0035) |
| B: *EnvPerf-R× Inactive* | 0.0054 | 0.0203*** | 0.0171*** |
| | (0.0059) | (0.003) | (0.0028) |
| *Size* | −5.2482 | 9.099*** | 9.2512*** |
| | (5.3648) | (0.0896) | (0.0908) |
| *Sales turnover* | −52.4964*** | 5.5199*** | 5.5686*** |
| | (6.4368) | (0.186) | (0.1909) |
| *Leverage* | 67.7884** | −1.1312*** | −2.4263*** |
| | (29.9031) | (0.425) | (0.4424) |
| *Tobin's q* | −0.7694*** | 0.095*** | 0.0221* |
| | (0.2677) | (0.0128) | (0.0133) |
| *ROA* | −1.767*** | 0.0031 | −0.0007 |
| | (0.2972) | (0.0043) | (0.0048) |
| *GDPperCap* | −22.4132 | 2.8697*** | 5.4605*** |
| | (16.437) | (0.3556) | (0.3589) |
| *CO2toGDP* | 197.1702** | −36.7806*** | −24.6261*** |
| | (83.7709) | (1.994) | (1.8452) |
| $R^2$ | 0.8533 | 0.8584 | 0.8512 |
| Observations | 192,716 | 480,679 | 531,338 |
| *P*-value (A) = (B) | 0.05 | 0.80 | 0.99 |
| Pair fixed effect | Yes | Yes | Yes |
| Year fixed effect | No | No | No |
| Year-Ind. adjusted | Yes | Yes | Yes |
| Related firm control | Yes | Yes | Yes |

**Table 4. Propagation effect of foreign environmental regulations through rival relationships and customer–supplier relationships**

The table reports the results of the difference-in-differences estimation of the regression model with the focal companies' environmental performance, measured by *CO2toRev* and *EnvScr*, as the dependent variable and the dummy variable *Regulation* as the independent variable. *Regulation-R* (*Regulation-F*) takes value one if a new environmental regulation has come into effect in the countries of the related (focal) companies. Panel A shows the estimated coefficient for the effect from competitors and customers for the entire sample. In Panel B, we split the observations in two groups based on two country-specific variables, the degree of environmental priority according to WVS survey, and *GDPperCap*. Dummy variable $1_{Yes}$ takes value one (zero) if the proenvironment percentage is higher (lower) in the focal firm's country than in the related firm's country,—Columns (1) and (2)—and if focal firm's country has lower (higher) *GDPperCap* than the country of the related firm (Columns 3 and 4). Dummy variable $1_{No}$ is defined in a similar but opposite way. The *p*-value is for the test of the hypothesis that the coefficients of the interaction terms with $1_{Yes}$ (A) and $1_{No}$ (B) are equal. The model also includes the lagged values of control variables for both focal and related companies: the logarithm of total assets (*Size*), the ratio of total sales to total assets (*Sales turnover*), the ratio of total debt to the book value of total assets (*Leverage*), the market-to-book equity ratio (*Tobin's q*), and the return on assets (*ROA*), as well as country variables *GDPperCap* and *CO2toGDP*, except Column (7) of Panel A that does not control for *CO2toGDP.* All the company variables are year-industry adjusted. All the regressions control for pair fixed effects. For the sake of space, we do not report the results for the control variables. The data cover the period from 2004 to 2019. The standard errors shown in parentheses are clustered at the firm-pair level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

**Panel A. Entire sample**

| | Competitor effect | | | | Customer effect | | |
|---|---|---|---|---|---|---|---|
| | *CO2toRev* | | *EnvScr* | | *EnvScr* | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| *Regulation-R* | −12.2816*** | −14.374*** | −0.4268 | −0.4011 | −0.0847 | −0.1961 | 1.7073*** |
| | (4.237) | (4.2362) | (0.3121) | (0.2495) | (0.2511) | (0.2517) | (0.2475) |
| *Regulation-F* | | −9.1637** | | 0.6261*** | | 1.1074*** | |
| | | (4.4573) | | (0.2162) | | (0.2513) | |
| $R^2$ | 0.9065 | 0.9065 | 0.9036 | 0.9037 | 0.9191 | 0.9191 | 0.9178 |
| Observations | 63,009 | 63,009 | 87,455 | 87,455 | 66,207 | 66,207 | 66,266 |
| Pair fixed effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year-Ind. Adjusted | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Control for *CO2toGDP* | Yes | Yes | Yes | Yes | Yes | Yes | No |
| Focal firm control | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Related firm control | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

**Table 4. Continued.**

**Panel B. Country-level differences and the propagation effect of foreign competitor country regulations on focal firms' *CO2toRev***

| | ***Higher proenvironment*** | | ***Lower GDP*** | |
|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** |
| A: *Regulation-R* × $1_{Yes}$ | −17.4221*** | −18.9694*** | −10.5948** | −13.5462*** |
| | (4.6818) | (4.6579) | (5.1385) | (5.1172) |
| B: *Regulation-R* × $1_{No}$ | 4.9790 | 1.7789 | −14.9352*** | −15.564*** |
| | (6.7411) | (6.8563) | (5.6434) | (5.6604) |
| *Regulation-F* | | −9.4758* | | −9.1631** |
| | | (4.8743) | | (4.4536) |
| $R^2$ | 0.8967 | 0.8967 | 0.9065 | 0.9065 |
| Observations | 59,844 | 59,844 | 63,009 | 63,009 |
| *P*-value (A) = (B) | 0.00 | 0.00 | 0.51 | 0.76 |
| Pair fixed effect | Yes | Yes | Yes | Yes |
| Year-Ind. adjusted | Yes | Yes | Yes | Yes |
| Focal firm control | Yes | Yes | Yes | Yes |
| Related firm control | Yes | Yes | Yes | Yes |

**Table 5. The effects of industry concentration and relative firm strength on propagation between competitors**

The table reports the results of the firm-pair fixed-effect estimation of the regression model with the focal companies' environmental performance, measured by *CO2toRev*, as the dependent variable and one-year lagged corresponding environmental performance of their rivals as the independent variable. In the first column, the indicator $1_{Yes}$ takes value one for firms in industries with above-median Herfindahl–Hirschman index (HHI) and $1_{No}$ takes the value of one if the opposite is true. In Columns (2) to (6), we split the observations based on variables market share (*MktShr*), size, number of links and centrality as supplier and as customer, respectively. For each variable, the indicator $1_{Yes}$ takes value one when a focal firm has a higher value on that variable than its rival, and $1_{No}$ takes the value of one if the opposite is true. The model also includes the lagged values of control variables for both focal and related companies: the logarithm of total assets (*Size*), the ratio of total sales to total assets (*Sales turnover*), the ratio of total debt to the book value of total assets (*Leverage*), the market-to-book equity ratio (*Tobin's q*), and the return on assets (*ROA*), as well as country variables *GDPperCap* and *CO2toGDP*. For the sake of space, we do not report the results for the control variables. The data cover the period from 2004 to 2019. The standard errors shown in parentheses are clustered at the firm-pair level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

| | **High HHI** | **Higher MS** | **Larger size** | **Larger # of links** | **Centrality as supplier** | **Centrality as customer** |
|---|---|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** |
| A: *CO2toRev-R* × $1_{Yes}$ | 0.0605*** | 0.0233*** | 0.0279*** | 0.0093 | 0.0204** | 0.0300*** |
| | (0.0161) | (0.0077) | (0.0101) | (0.0076) | (0.0084) | (0.0091) |
| B: *CO2toRev-R* × $1_{No}$ | 0.0276*** | 0.0683*** | 0.0454*** | 0.0387*** | 0.0381*** | 0.0474*** |
| | (0.0074) | (0.0202) | (0.012) | (0.0118) | (0.0103) | (0.0156) |
| $R^2$ | 0.922 | 0.9204 | 0.9161 | 0.9173 | 0.9217 | 0.9176 |
| Observations | 62,366 | 62,364 | 63,739 | 61,549 | 60,888 | 62,316 |
| *P*-value (A) = (B) | 0.05 | 0.04 | 0.26 | 0.04 | 0.17 | 0.33 |
| Pair fixed effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Year-Ind. adjusted | Yes | Yes | Yes | Yes | Yes | Yes |
| Focal firm control | Yes | Yes | Yes | Yes | Yes | Yes |
| Related firm control | Yes | Yes | Yes | Yes | Yes | Yes |

**Table 6. The effect of environmental materiality on the propagation between competitors**

The table reports the results of the firm-pair fixed-effect estimation of the regression model with the focal companies' environmental performance, measured by *CO2toRev*, as the dependent variable and one-year lagged corresponding environmental performance of their rivals as the independent variable. We use industry environmental materiality from the Sustainability Accounting Standards Board (SASB) and define an indicator $1_{Yes}$ which takes value one if both focal and related firms belong to industries with high environmental materiality, and an indicator $1_{NO}$ which takes value one if both belong to industries for which environmental issues are not material. Alt 1, Alt 2, and Alt 3 consider an industry to have high materiality if at least two, three and four of the six factors are rated as material by the SASB for this industry. The model also includes the lagged values of control variables for both focal and related companies: the logarithm of total assets (*Size*), the ratio of total sales to total assets (*Sales turnover*), the ratio of total debt to the book value of total assets (*Leverage*), the market-to-book equity ratio (*Tobin's q*), and the return on assets (*ROA*), as well as country variables *GDPperCap* and *CO2toGDP*. For the sake of space, we do not report the results for the control variables. The data cover the period from 2004 to 2019. The standard errors shown in parentheses are clustered at the firm-pair level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

| | **Alt 1**<br>**(1)** | **Alt 2**<br>**(2)** | **Alt 3**<br>**(3)** |
|---|---|---|---|
| A: *CO2toRev-R* × $1_{Yes}$ | 0.0391*** | 0.0408*** | 0.0436*** |
| | (0.0084) | (0.0085) | (0.0089) |
| B: *CO2toRev-R* × $1_{No}$ | −0.0120* | −0.0120 | −0.0130* |
| | (0.0071) | (0.0074) | (0.0077) |
| $R^2$ | 0.916 | 0.9175 | 0.9168 |
| Observations | 38,068 | 30,785 | 29,073 |
| *P*-value (A) = (B) | 0.00 | 0.00 | 0.00 |
| Pair fixed effect | Yes | Yes | Yes |
| Year-Ind. adjusted | Yes | Yes | Yes |
| Focal firm control | Yes | Yes | Yes |
| Related firm control | Yes | Yes | Yes |

**Table 7. Comparing degree of propagation based on the level and direction of change**

The table reports the results of the firm-pair fixed-effect estimation of the regression model with the focal companies' environmental performance, measured by *CO2toRev*, as the dependent variable and one-year lagged corresponding environmental performance of their rivals as the independent variable. In Column (1), the indicator $1_{Yes}$ ($1_{NO}$) takes value one if focal firms' environmental performance at time $t-1$ is above (below) median and takes zero otherwise. In Column (2), the indicator $1_{Yes}$ ($1_{NO}$) takes value one if the rival firms' environmental performance at time $t-1$ increases (decreases) and takes zero otherwise. The model also includes the lagged values of control variables for both focal and related companies: the logarithm of total assets (*Size*), the ratio of total sales to total assets (*Sales turnover*), the ratio of total debt to the book value of total assets (*Leverage*), the market-to-book equity ratio (*Tobin's q*), and the return on assets (*ROA*), as well as country variables *GDPperCap* and *CO2toGDP*. For the sake of space, we do not report the results for the control variables. The data cover the period from 2004 to 2019. The standard errors shown in parentheses are clustered at the firm-pair level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

| | **Focal with high at $t-1$** (1) | **Rival decreases at $t-1$** (2) |
|---|---|---|
| A: *CO2toRev-R* × $1_{Yes}$ | 0.0354*** | 0.0423*** |
| | (0.0079) | (0.012) |
| B: *CO2toRev-R* × $1_{No}$ | −0.0143 | 0.0232** |
| | (0.0098) | (0.0092) |
| $R^2$ | 0.9145 | 0.9216 |
| Observations | 59,512 | 51,330 |
| *P*-value (A) = (B) | 0.00 | 0.19 |
| Pair fixed effect | Yes | Yes |
| Year-Ind. adjusted | Yes | Yes |
| Focal firm control | Yes | Yes |
| Related firm control | Yes | Yes |

**Table 8. Geographical subsamples**

The table reports the results of the firm-pair fixed-effect estimation of the regression model with the focal companies' environmental performance, measured by *CO2toRev*, as the dependent variable and one-year lagged corresponding environmental performance of their rivals as the independent variable. We use three different subsamples based on the geographical location of the focal firms and their rivals, if both belong to the same country, if they are from different countries, and if they are headquartered in different regions. The model also includes the lagged values of control variables for both focal and related companies: the logarithm of total assets (*Size*), the ratio of total sales to total assets (*Sales turnover*), the ratio of total debt to the book value of total assets (*Leverage*), the market-to-book equity ratio (*Tobin's q*), and the return on assets (*ROA*), as well as country variables *GDPperCap* and *CO2toGDP*. For the sake of space, we do not report the results for the control variables. The data cover the period from 2004 to 2019. The standard errors shown in parentheses are clustered at the firm-pair level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

| | **Same country** | **Different countries** | **Different regions** |
|---|---|---|---|
| | **(1)** | **(2)** | **(3)** |
| *CO2toRev-R* | 0.0567*** | 0.0246*** | 0.0282*** |
| | (0.0158) | (0.0082) | (0.0083) |
| $R^2$ | 0.9189 | 0.911 | 0.9117 |
| Observations | 20,407 | 44,938 | 33,979 |
| Pair fixed effect | Yes | Yes | Yes |
| Year-Ind. adjusted | Yes | Yes | Yes |
| Focal firm control | Yes | Yes | Yes |
| Related firm control | Yes | Yes | Yes |

**Table 9. Other measures of environmental performance**

The table reports the results of the firm-pair fixed-effect estimation of the regression model with the focal companies' environmental performance as the dependent variable and one-year lagged environmental performance of their rivals as the independent variable. *Policy* is an indicator variable for whether the company has a policy for reducing future emissions. In Columns (1) and (2), we model the effect of rival firms' *Policy* on focal firms' *Policy*. In Columns (3) and (4), we model the effect of rival firms' *Policy* on focal firms' *CO2toRev*. The model also includes the lagged values of control variables for both focal and related companies: the logarithm of total assets (*Size*), the ratio of total sales to total assets (*Sales turnover*), the ratio of total debt to the book value of total assets (*Leverage*), the market-to-book equity ratio (*Tobin's q*), and the return on assets (*ROA*), as well as country variables *GDPperCap* and *CO2toGDP*. For the sake of space, we do not report the results for the control variables. The data cover the period from 2004 to 2019. The standard errors shown in parentheses are clustered at the firm-pair level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

| | ***Policy* to *Policy*** | | ***Policy* to *CO2toRev*** | |
|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** |
| *EnvPerf-R* | 0.0198*** | 0.0047 | −10.3685*** | −3.5504 |
| | (0.0045) | (0.0044) | (3.783) | (4.2773) |
| $R^2$ | 0.8318 | 0.8058 | 0.9619 | 0.9070 |
| Observations | 170,050 | 164,455 | 103,345 | 100,027 |
| Pair fixed effect | Yes | Yes | Yes | Yes |
| Year fixed effect | Yes | No | Yes | No |
| Year-Ind. adjusted | No | Yes | No | Yes |
| Focal firm control | Yes | Yes | Yes | Yes |
| Related firm control | Yes | Yes | Yes | Yes |

# Appendix

## Table A1. Variable descriptions

The table gives the variable definitions and related data sources.

| Variable | Definition |
|---|---|
| ***Environmental*** | |
| CO2 emissions scaled by revenue (*CO2toRev*) | Defined as total CO2-equivalent emissions—the sum of the direct (Scope 1) and indirect (Scope 2) emissions—in tons per USD million of revenue. Source: Eikon. |
| Environment score (*EnvScr*) | The score combines three category scores—emissions, resource use, and innovation—which are in turn based on a total of 68 metrics. Source: Asset4 |
| Policy | An indicator variable for whether the company has a policy for reducing future emissions. Source: Asset4. |
| ***Firm characteristics*** | |
| Active dummy | Takes value one for the period of reported relationships of each pair and zero otherwise. Source: FactSet Revere. |
| Centrality in supply chain network | The supply-chain matrix at a given point in time is denoted by the square adjacency matrix $\boldsymbol{A}$, where the element $A_{ij}$ of the matrix is equal to one if the company in column $j$ is the customer of company in row $i$ and zero otherwise. The eigenvector that corresponds to the largest eigenvalue of the product matrix $\boldsymbol{A'A}$ defines the vector of customer centrality. The supplier centrality is defined similarly but with $\boldsymbol{A'A}$ replaced by $\boldsymbol{AA'}$ (Wu, 2015). |
| Inactive dummy | Takes value one for the period which contains firm-pair years outside the reported relationship period and zero otherwise. Source: FactSet Revere. |
| Leverage | The ratio of total debt to the book value of total assets. Source: Eikon. |
| Market share (*MktShr*) | Defined 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. Source: Eikon |
| Number of customers | 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. Source: FactSet Revere. |
| Number of suppliers | 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. Source: FactSet Revere. |
| Return on assets (*ROA*) | Income after taxes for the fiscal period divided by the total assets at the beginning and the end of the year. Source: Eikon. |
| Sales turnover | Defined as the ratio of total sales to total assets. Source: Eikon. |
| Size | The logarithm of total assets. Source: Eikon. |
| Tobin's $q$ | The market value of equity divided by the book value of equity. Source: Eikon. |

**Table A1. Variable descriptions (continued)**

| Variable | Definition |
| --- | --- |
| ***Industry characteristics*** | |
| HHI | Defined as the sum of squared market share of individual firms in the corresponding industry. Captures the industry concentration. Source: Eikon |
| Materiality | Three alternative definitions for considering firms' materiality are used. Alt 1, Alt 2, and Alt 3 consider environment to be material for companies if at least two, three, and four of the six factors are rated as material by the SASB, respectively. Immaterial includes those firms for whom environment considerations are not material for either of the firms by any of the materiality factors. Source: SASB |
| ***Country characteristics*** | |
| *CO2toGDP* | Defined as kilograms of CO2 emissions per PPP $ of GDP. Source: World Bank Database |
| *GDPperCap* | In current USD thousand (logged). Source: World Bank Database |
| Geographic regions | Africa, Asia, Central America, EU, Europe ex. EU, Middle East, North America, Oceania and South America |
| Proenvironment | The degree of environmental priority in a country. Source: WVS survey |
| *Regulation* dummy | Takes value one if a new environmental regulation has come into effect in the countries of the companies related to the focal company. The R and F suffixes indicate whether the regulation has come into effect in the countries of the related (*Regulation-R*) or focal (*Regulation-F*) firms. Source: Carrot & Sticks |