Director networks and carbon emissions[1]

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Abstract

This paper studies the impact of board directors' social networks on firm carbon emissions. We investigate both the effects from directly connected social peers and the effects of firms' board connectedness in the whole director network. Analyzing 3,304 firms in 35 countries from 2003 through 2020, we identify causal influence of social peers on absolute carbon emission levels and emission intensity. Peer effects are primarily driven by firms mimicking peers with relatively lower emissions (*better peers*) rather than peers with higher emissions (*worse peers*). However, for firms in high-emitting sectors, we find a stronger better-peer effect in terms of emission intensity but a stronger worse-peer effect in terms of emission level. These contrasting results suggest that firms appear to use emission intensity as the primary metric to benchmark their emission performance against their social peers. This points to a caveat regarding the role of social network propagation since Net Zero Carbon pledges are about reducing absolute emissions rather than emission intensity. We do not observe any association between board connectedness and emissions, indicating limited advantages of board connectedness for carbon emission reductions. However, high board connectedness is associated with higher environmental pillar scores, suggesting a potential greenwashing behavior.

Keywords: Carbon emissions, Social networks, Peer effects, Board connectedness, Greenwashing

JEL classifications: G30, M14, Q5

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1. Introduction

The board of directors should play an important role in implementing and monitoring decarbonization efforts, given the long-term focus and strategic nature of corporations' emission practices. The role of the board of directors is also manifested by regulators. From January 1, 2024, the ultimate responsibility for companies' emissions reporting and compliance with the EU's CSRD regulations falls on their boards. Moreover, corporate directors face increased scrutiny regarding their success in reducing firms' carbon emissions.[6] Director networks could serve as important conduits for boards to learn best practices on how to reduce emissions and also apply peer pressure to do so. On the flip side, director networks could also serve as coordination devices for lobbying or greenwashing efforts.

In this paper, we investigate the effects of directors' social network connections on firm carbon emissions. We investigate both the effects from directly connected social peers and the effects of board connectedness in the whole director network (cf. Fracassi, 2017). Focusing on carbon emissions as a measure of environmental performance is important for several reasons. First, it is a key variable in mitigating climate change with the likelihood and speed of firms' decarbonization efforts having direct consequences for transitioning to a low-carbon economy (Althor et al., 2018; Davis et al., 2010). Second, how board connections matter for corporate carbon emissions is not well understood. Prior studies finding that director connections have a positive impact on corporate sustainability commonly focus on aggregate measures of sustainability and environmental performance (Amin et al., 2020; Alves, 2021; Iliev & Roth, 2023).[7] Third, although investors may care about firms' actual carbon emissions, studies also report that many investors rely on the aggregate scores (Rzeźnik, Hanley, & Pelizzon, 2021) and care about the presence, not the

[6] For example, in 2022 the directors sitting on Shell's board were personally threatened with legal action for failing to reduce the company's carbon emissions (Sterling, 2022). In an even crisper example, a small group of activist investors defeated Exxon Mobil's board and installed three directors to push the company to reduce its carbon footprint (Phillips, 2021).

[7] Aggregate ratings are multifaceted constructs, encompassing both intentions (e.g., setting targets for emissions or formulating environmental policies) and real actions (e.g., actual carbon emissions). Moreover, ratings from different providers differ substantially from each other (Berg, Koelbel, & Rigobon, 2022). Thus, it is not given that the positive effects found for aggregate ratings will hold for carbon emissions specifically.

magnitude, of sustainability impact (Heeb et al., 2023). Since reducing emission is often costly, firms may have incentives to improve their aggregate environmental score through, for example, declaring intentions without real reductions in carbon emissions (Asgharian et al., 2024; In & Schumacher, 2021; Kacperczyk & Peydró, 2022). Therefore, whether director networks aid in reducing, or even affect, firms' actual carbon emissions remains an open question.

We collect data from BoardEx on professional ties among 44,464 individual board directors sitting on the boards of 3,304 unique firms headquartered in 35 countries between 2003 and 2020. We match these data to firms' carbon emissions from Asset4, considering both the level of carbon emissions and carbon intensity - the level of emissions scaled by revenue. This consideration is motivated by the ongoing debate regarding the appropriate way to measure firms' emissions performance. Bolton and Kacperczyk (2021; 2024) for example argue that emission level is more suitable since regulations aiming to limit emissions are more likely to target activities where the level of emissions is the highest. Aswani, Raghunandan, and Rajgopal (2024a, 2024b) on the other hand argue that emission intensity better captures a firm's emissions performance since this metric avoids mechanical correlations with firm size. Without taking a stance on which measure of carbon emissions is the better, we follow the recent trend to consider both (Atilgan et al., 2023).

Our first analysis investigates the propagation effects of carbon emissions between pairs of socially connected firms. Establishing a causal relationship between director connections and corporate carbon emissions is challenging because the composition and operations of a firm's board and its emissions could be jointly determined. We employ two identification strategies to address this concern. First, we address the possibility of reverse causality and exploit exogenous variation from the staggered introduction of mandatory carbon-emissions regulations in foreign peers' countries. A focal firm is considered treated if the foreign peer is affected by a new regulation. Hence, this identification strategy relies on a difference-in-difference (DiD) design using exposure to exogenous mandatory carbon-regulation shocks as the channel through which the focal firm is affected (cf. Iliev & Roth, 2023). Second, to address assortative matching resulting from firms with similar carbon-emissions practices and strategies hiring the same directors, we compare the sample of "connected" firm-pair years to an "unconnected" placebo sample of the same firm pairs in the years outside their connected periods (cf. Asgharian et al., 2024). Both identification tests show causal propagation of carbon-emission levels and emission intensity among socially connected companies.

The propagation effect we identify could, in principle, be symmetric, depending on the nature of information and norms shared by connected directors. On the one hand, directors from companies that have successfully implemented carbon-reduction strategies may bring this knowledge to the boardroom and inform their peers about the benefits of such strategies. Directors of green firms may also exert moral pressure on connected directors of browner firms. Thus, the sharing of best practices and the social norm to reduce carbon footprints can foster a more proactive environmental stance among firms interconnected through these social ties. On the other hand, if directors belong to networks where lax environmental standards are the norm, this attitude can permeate through the firms they govern. Prior evidence indeed suggests that boardroom connections can facilitate the spread of bad norms, practices, and information, leading to negative outcomes (Bizjak, Lemmon, & Whitby, 2009; Kuang & Lee, 2017). In such scenarios, social networks may facilitate firms' focus on shareholder value maximization and deter firms from spending money on carbon emission reductions (Fooks et al., 2013; Atilgan et al., 2023). Additionally, information on greenwashing or on voluntary environmental programs to preempt more stringent governmental regulation rather than reducing actual emissions is more likely to transmit (cf. Malhotra, Monin & Tomz, 2019). This phenomenon can be particularly problematic for firms or sectors with historically high carbon footprints where such behavior is normalized. The normalization and reinforcement of such norms through social network ties could result in an overall increase in emissions, as firms conform to the less rigorous emission standards upheld by their network peers (Bryant, Griffin & Perry, 2023).

To investigate if directors' social connections are a force of good or evil in reducing emissions, we compare propagation effects from peers that have lower emissions than the focal firm (*better peers*) to effects from peers with higher emissions (*worse peers*). We find that the peer effect is mainly driven by firms emulating peers with relatively lower emissions. However, for firms in high-emitting sectors, a stronger better-peer effect in emission intensity is associated with an unintended consequence: a stronger worse-peer effect in terms of absolute emission levels. This effect appears to be driven by the fact than in high-emitting sectors, peer firms are more likely to simultaneously have lower intensity and higher emissions levels than the opposite combination. In the full sample, both combinations are equally likely. Therefore, our findings indicate that firms predominantly use emission intensity to benchmark their emission performance against their social peers. However, focusing on following social peers with lower emission intensity can be a double-edged sword, particularly for firms in high-emitting sectors. This highlights a caveat regarding the role of social-network propagation, as Net Zero Carbon pledges emphasize reducing absolute emission levels rather than merely improving emission intensity.

Finally, we complement the peer-effect analysis by examining the effect of overall board connectedness on firms' carbon emissions and environmental scores. The connectedness analysis explores the position of firms in the whole director network, as opposed to the average effect of directly related peers, captured by the peer-effect analysis. Similar to peer effects, however, board connectedness in the network may exert both positive and negative effects on emissions. On the one hand, connectedness provides informational and resource advantages to learn best practices (Amin et al., 2020). Well-connected firms may also be prone to self-regulate because of decreased information asymmetry (Baker & Faulkner, 2004). On the other hand, well-connected directors often accumulate reputation and credibility (Bitektine, 2011). There is a risk that such directors could exploit this public trust and admiration to hide misdeeds (Kuang & Lee, 2017; Yu & Yu, 2011). The net effect of board connectedness on firms' carbon emissions therefore remains an open question.

To address endogeneity concerns due to omitted variables and reverse causality between board connectedness and carbon emissions, we restrict our sample to firms whose boards remain the same from one year to the next (following Amin et al., 2020). In this case, any changes in board connectedness should be exogenous to the firm and rely on the changes in connectedness of other firms. We find no evidence of causal effect of board centrality on either emission level or emission intensity. We do however confirm prior findings on a positive effect of board centrality on aggregate environmental pillar score (Amin et al., 2020). Our results could be suggestive of greenwashing among firms with well-connected boards as improvements in environmental scores are not accompanied by actual emission reduction. Hence, our findings challenge the view that board connectedness has a positive effect on environmental performance.

Our paper's main contribution is examining the effects of directors' social networks on firms' carbon emissions. Recent work shows that directors' social-network connections are important to firms' Environmental, Social, and Governance (ESG) performance because such connections provide access to relevant information and expertise (Amin et al., 2020; Alves, 2021; Iliev & Roth, 2023). These prior empirical studies use aggregate ESG scores to establish the relevance of director social networks in improving firms' sustainability. However, the prerequisites and incentives for improving aggregate scores may differ from those for managing actual carbon emissions. While some studies find that markets adequately price carbon risks (e.g., Bolton & Kacperczyk, 2021), some find that market forces alone are insufficient and stress the need for government intervention (e.g., Atilgan et al., 2023). Thus, our emphasis on carbon emissions adds an important, more focused, perspective on the role of directors' networks in tackling climate change.

Next, we contribute to the literature debating absolute and scaled emission measures (e.g., Bolton & Kacperczyk, 2021, 2024; Aswani, Raghunandan, & Rajgopal, 2024a, 2024b). We show evidence that firms use emission intensity as the primary metric to benchmark their emission performance against social peers. We also show that the focus on emission intensity can backfire in high-emitting sectors where the tendency to follow social peers with lower emission intensity at the same time leads to following peers with higher emission levels. These results suggest some tension between high-emitting individual firms' objective functions and those of society.

Finally, we contribute to the growing literature on drivers of corporate emission reductions. Prior studies underscore the role of several corporate governance factors including ownership structure (Azar et al., 2021; Shive & Forster, 2020) and gender diversity at the managerial levels (Altunbas et al. 2022). Bartram, Hou and Kim, (2022) examine the role of climate policies. Prior research also investigates the role of network effects among competitors and supply-chain partners in shaping emission performance (Asgharian et al., 2024). We contribute to this literature by examining a different type of network: the social connections between corporate board directors. We show that direct social connections between directors are also an important conduit for transmission of carbon-emissions performance. However, our results also point to the limited usefulness of overall board connectedness in improving firms' environmental performance. We find no evidence of a link between overall board connectedness and carbon emissions, neither in the general sample nor in the high-emitting sectors, suggesting that central positions in the overall social network of directors are not conducive to transmitting carbon emissions' more complex information and norms.

The rest of the paper is organized as follows. We present the data in Section 2. Section 3 provides the empirical results of our main analyses. Section 4 concludes.

2. Data and variables

Our full sample covers 3,304 unique firms headquartered in 35 countries and 44,464 individual board directors for the 2003–2020 period and is constructed by matching three datasets: BoardEx, Asset4, and Eikon. BoardEx contains data on board-director social-network connections; Asset4 provides data on emissions and environmental performance; Eikon provides accounting data. We drop observations with missing data on country- and firm-level controls and observations from countries with fewer than 10 firm-year observations.

For each director or executive, BoardEx compiles a historical profile containing the past employment history, current employment, board memberships, educational background, and social activities such as memberships in social clubs and charities. We focus on employment connections. For each individual board director in our sample, we consider his/her connections to other directors at other ESG-reporting firms for which we have information from Asset4. We consider two board directors socially connected if they currently work in the same company or if they worked in the same company in the past. Furthermore, two firms are socially connected if they share at least one current director or if their directors are connected through shared employment in other firms, either currently or in the past. For each firm pair, BoardEx allows us to identify the first and last year of the social connection. Following Asgharian et al. (2024), we use this information to form a *connected* sample—firm-pair years falling within the reported period—and an *unconnected* sample, years outside the reported connection period for the same pairs and for which we could obtain the required environmental and accounting data.

Asset4 is one of the major providers of ESG ratings and carbon-emissions data for companies worldwide. We assess two measures of emissions; *Emission level*, the log of total carbon emissions (defined as Scope 1 emissions plus Scope 2 emissions by Asset4) in tons and *Emission intensity* which is total carbon emissions scaled by revenue. To mitigate the impact of outliers, we winsorize emission intensity at the 95th percentile.

We include several governance-related controls shown to be associated with sustainability performance (e.g., Amin et al., 2020; Kara et al., 2022; McGuinness, Vieito, & Wang, 2022): *Board size* (number of directors on the board), *Board diversity* (the proportion of women on the board), *Board independence* (the proportion of independent directors on the board), *Board tenure* (the average tenure of board directors), and *Board age* (average age of board directors). We use *CEO duality* (equal to 1 if the CEO also chairs the board) as a proxy for CEO power (Jiraporn & Chintrakarn, 2013). We also control for firm characteristics found to influence firms' sustainability and emissions (e.g., Chen, Dong, & Lin, 2020; Dyck et al., 2019; Asgharian et al., 2024): *Size* (the logarithm of total assets)[8], *RoA* (Return on Assets), *Tobin's Q* (market

[8] Another size variable besides total assets that should influence firms' emission levels is revenue. To ensure robustness, we also control for lagged total revenue, instead of lagged total assets, in the regressions where the dependent variable is emission levels. However, we do not control for lagged total revenue if emission intensity is the dependent variable as there may be endogeneity concerns due to emission intensity being calculated from revenue.

value of equity divided by the book value of equity), *Leverage* (long- and short-term debt over total assets), and *Cash ratio* (the ratio of cash to the book value of total assets). In general, these board and firm characteristics are also found to be correlated with the presence of well-connected directors as such directors tend to serve on boards of larger and better-performing firms (Intintoli, Kahle, & Zhao, 2018; Masulis & Mobbs, 2014). They may also indirectly affect peer firms' emission performance through two primary factors: (1) the matching of social peers based on similar governance characteristics (see Bouwman, 2011), and (2) the transmission of corporate policies, like leverage decisions, through corporate networks (e.g., Fracassi, 2017). Therefore, to isolate peer effect in emission performance, we control for the characteristics of both the focal firm and the peers in firm-pair-level regressions.

Further, we control for two country-level variables, based on the location of firms' headquarters: *GDP per capita* in USD thousand, capturing the country's wealth, and *CO_2 to GDP*, defined as CO_2 emissions in kilograms per PPP$ of GDP and measuring the economy's overall carbon intensity. The data are collected from the World Bank. In firm-pair level regressions, we control for *GDP per capita* and *CO2 to GDP* of the focal firms' and the peers' country of headquarters. To mitigate the effects of extreme values, we winsorize all control variables at the 1st and 99th percentiles.

Table 1 reports descriptive statistics for the main variables for the full sample. We report the mean, standard deviation, minimum, median, and maximum of the main variables. The table also indicates the number of firm-year observations and the number of firms. On average, firms in our sample have $7.1 billion in asset value, a leverage ratio of 25%, and a profitability rate of 5.3%. Regarding board characteristics, the average board size is 12 directors, with 17% being female and 62% being independent. The average age of directors is 60 years, and the average board tenure is 7 years.

[Insert Table 1 here]

3. Empirical results

3.1. Peer-effect analysis: Addressing reverse causality

First, we address the possibility of reverse causality. We adopt a quasi-natural experimental approach similar to Iliev and Roth (2023) by exploiting sequential introductions of carbon emission regulations in peer firms' headquarter countries. We hand collect data on country-level mandatory carbon-emissions regulations from "Carrots & Sticks" reports, a series of publications that analyze global trends in sustainability reporting focusing on mandatory and voluntary policies that influence the ESG impact of businesses worldwide.[9] We employ the *stacked regression* approach proposed by Baker, Larcker, and Wang (2022) to account for staggered DiD specification. We use a sub-sample of firms that have peer firms headquartered in countries different from their own headquarter countries. We define a firm, f, as treated in year *t* if any of f's peer firms with headquarters in a foreign country become subject to a mandatory carbon-emissions regulation that comes into effect in that year. For each treatment year, we construct a cohort of treated and never-treated control firms using firm-year observations. We stack the cohorts and estimate the following regression.

$$Emissions_{f,c,t} = \lambda Regulation_{f,c,t} + \rho X_{f,c,t-1} + \mu_{f,c} + \theta_{c,t} + \varepsilon_{f,c,t}, \quad (1)$$

where $Emissions_{f,c,t}$ denotes the firm *f*'s *Emission level* or *Emission intensity* in cohort *c* at time *t*. $Regulation_{f,c,t}$ is a dummy variable equal to zero at the beginning of the period and one going forward once a mandatory carbon-emissions regulation has come into effect in the country where any of the firm's peer firms are headquartered. The coefficient λ reflects the DiD effect of carbon-emissions regulation in the country of peer firm on the focal firm. $X_{f,c,t-1}$ is a vector of focal firm control variables in cohort *c* at time *t-1*. We also control for firm-cohort fixed effects, $\mu_{f,c}$, and year-cohort fixed effects, $\theta_{c,t}$.

[9] The reports are a collaborative effort involving various organizations, including the UN Environment Programme. The mandatory regulations are described in Appendix table A.2.

Table 2 reports the coefficients of the DiD effects. The first column shows that the coefficient of carbon-regulation changes in foreign peer firms' countries is negative and highly statistically significant regarding *Emission level*. This result points to a causal effect of foreign peer firms on focal firms' carbon-emissions level. The coefficient implies that the introduction of a carbon regulation in the peer firm's country conveys a 9.0% reduction in the focal firm's total emissions.[10] The second column shows that the coefficient of regulation changes is negative and significant at a ten percent level for *Emission intensity*. The estimate of -0.219 implies a reduction of 6.1 % relative to the full sample mean emission intensity (3.57 ton/million USD, See Table 1).

The signs of the coefficients of the control variables show that more gender-diversified boards are associated with lower emissions. Larger firms have higher carbon emission levels but lower emission intensity. Regarding the country-level controls, we find a positive significant association between *CO2 to GDP* and carbon emissions. However, these results should be interpreted with caution since the effects represent correlations rather than causal relationships. To summarize, the DiD analysis provides evidence of a causal effect of directors' social connections on firms' carbon-emissions levels and emission intensity.

[Insert Table 2 here]

3.2. Peer-effect analysis—Pairwise evidence in connected and unconnected periods

In this section, we investigate pairwise propagation of carbon emission performance among socially connected firms. The unit of this analysis is the firm-pair year, where each pair consists of a focal firm, *f*, and a peer firm, *p*. Firms tend to appoint new directors whose existing directorships are at firms with similar governance practices (see Bouwman, 2011). This matching of firms might confound the impact of peer influences in emission strategies. To mitigate the concern about selection bias, we follow Asgharian et al. (2024) by comparing the sample of connected firm-pair years to a placebo sample of firm-pairs in the years

[10] The coefficient has almost the same estimate and level of significance in the estimation that controls for lagged total revenue instead of total assets.

outside the connected-sample period. If the estimated degree of peer influence is significantly higher in the connected period than in the placebo period, the peer influence should be driven by existing peer connections rather than alignment of emission strategies prior to the connections.

A firm-pair year, *fpt*, is included in the sample if the year *t* falls within the connection period of firm *f* and firm *p*. This is the connected sample. Conversely, a firm-pair year, *fpt*, is categorized as unconnected if firms *f* and *p* are not connected in year *t*, but have a connection at some point during the study period from 2004 to 2020. For the purpose of analytical comparison, we combine the two samples and define two dummy variables to categorize observations as belonging to either of the samples. The *Connected* dummy takes value one if firm-pair year *fpt* belongs to the connected sample and value zero if it belongs to the unconnected sample. The *Unconnected* dummy is defined in reverse, *Unconnected* = (*1 − Connected*). We interact peer firms' emissions variables with both dummies, rather than with the *Connected* dummy only, because we are interested in the effects in both samples. The resulting model is

$$Emissions\_F_{f,t} = \alpha_{f,p} + \alpha^*_{f,p} + \lambda_t + \beta_1 Emissions\_P_{p,t-1} \times Connected + \beta_2 Emissions\_P_{p,t-1} \times Unconnected + \rho\, Connected + \gamma_f' X_{f,t-1} \times Connected + \gamma_p' X_{p,t-1} \times Connected + \gamma_f' X_{f,t-1} \times Unconnected + \gamma_p' X_{p,t-1} \times Unconnected + \varepsilon_{fp,t}, \quad (2)$$

where $Emissions\_F_f$ denotes *Emission level* or *Emission intensity* for the focal firm *f*, and $Emissions\_P_p$ represents *Emission level* or *Emission intensity* for the peer firm *p*. $\alpha_{f,p}$ and $\alpha^*_{f,p}$ are the firm-pair fixed-effect parameters in the connected and unconnected periods, respectively. λ_t is the year fixed-effect parameter. $X_{f,t-1_f}$ and $X_{p,t-1}$ are control variables of the focal firm and the peer firm in year *t*-1, respectively. All the control variables are also interacted with the two dummies to allow for possible differences in their effect on focal firms' emissions in the two different periods. This is especially important for peer firms' control variables, as their influence on focal firms' emission is likely to differ between the connected and the unconnected periods. To prevent multicollinearity, the explanatory variables themselves are not used in the regression, only in conjunction with their interaction with the dummy variables. β_1 and β_2 are the parameters of interest and show the effect of the peer firm's *Emissions_P* at time $t-1$ on the focal firm's $Emissions\_F$ at time *t*, depending on whether *t* falls in the connected sample or the unconnected sample. In the absence (presence) of selection bias, we expect β_2 to be zero (positive). If, in addition, peer firms causally affect focal firms' emissions, we expect $\beta_1 > \beta_2$. To investigate whether the effect is indeed more pronounced in the connected sample, we conduct a *t*-test on the statistical significance of the difference between β_1 and β_2.

Table 3 presents the estimation results for *Emission level* and *Emission intensity*. The coefficients on these variables of the peer company are positive and significant in the connected period. Column 1 shows a peer effect for *Emission level*. The positive and highly significant effect of 0.0120 implies that if the peer firm increases or decreases its log emission level by 10%, the focal firm would change its emissions by approximately 0.12%. Column 2 shows that a decrease in a peer firm's *Emission intensity* by one standard deviation implies a change in the focal firm's *Emission intensity* by 0.55% of a standard deviation, (the standard deviation of *Emission intensity* is 8.04 ton/million USD), which amounts to a reduction of approximately 1.2% relative to the full sample mean (3.57 ton/million USD). In both columns, the coefficient of *Emission_P* is close to zero and statistically insignificant in the unconnected period, indicating that firms do not align emission strategies with their potential peers outside the connected period. Furthermore, the *t*-test on the difference between the coefficients across the connected and unconnected periods returns a *p*-value below 0.01 for *Emission level* and below 0.10 for *Emission intensity.* These results indicate that the effects are not likely driven by selection.[11] However, the estimated peer effect on emission levels during the active period could reflect co-movement in sales, as emission levels are driven by sales. To explore this possibility, we control for the focal company's and the peer's the lagged log of total revenues instead of their total assets. The estimation yields similar results (not reported here), indicating

[11] Estimating the regression with a more conservative connected period, removing the first and last years of the connected and unconnected periods, accounts for measurement error in the dataset and yields similar results.

that the peer effect on emission levels is not driven by co-movement in sales. In sum, our results suggest genuine peer effects on emission performance of socially connected firms.

[Insert Table 3 here]

3.3. Effects from better- and worse-performing peers

Our earlier analyses show that firms' carbon-emissions levels are affected by social peers. This propagation effect could in principle be symmetric. Specifically, peer firms with high emissions could be dragging down the focal firm, just as the focal firm may emulate the greener practices of its low-emissions peers. Examining this dynamic is particularly crucial for high-emitting sectors, as those sectors play a key role in reducing carbon emissions concentration in the atmosphere.

To delve into this question, we investigate if firms primarily follow their better or their worse peers using pairwise regressions, for all the firms in the connected sample and for focal firms in high-emitting sectors, respectively. We construct two dummy variables: *Better_peer* is equal to one if the peer firm's *Emission level* or *Emission intensity* is lower than that of the focal firm at $t-1$. *Worse_peer* is defined in reverse. We then interact the peer firm's *Emission level* or *Emission intensity* with the two dummy variables. The regression is defined accordingly:

$$Emissions\_F_{f,t} = \alpha_{f,p} + \lambda_t + \beta^{*} Emissions\_P_{p,t-1} \times Better\_peer_{\ t-1} + \beta^{**} Emissions\_P_{p,t-1} \times Worse\_peer_{\ t-1} + \rho\ Better\_peer_{\ t-1} + \gamma_f' X_{f,t-1} + \gamma_p' X_{p,t-1} + \varepsilon_{fp,t}. \quad (3)$$

where $Emissions\_F_f$, $Emissions\_P_p$, $X_{f,t-1}$ and $X_{p,t-1}$ are defined as in Eq. (2). The coefficient β^{*}captures the effect if the peer had lower *Emission level* or *Emission intensity* than the focal firm, while β^{**} captures the effect if the peer had higher *Emission level* or *Emission intensity* than the focal firm.

Columns 1 to 4 of Table 4 show estimation results for the full connected sample. The coefficient estimates in Column 1 indicate that focal firms follow peers exhibiting a relatively lower *Emission levels* to a larger extent than they follow peers with higher *Emission levels*.[12] The better-peer effect is 27% larger than the effect from worse peers. As some sectors have higher emission levels than others due to the production nature, a high-emitting firm could still be considered as a better-performing peer if it emits less than the sectoral average. We explore this possibility by demeaning the variables in Eq. (3) by their sector-year averages and define better and worse peers based on sector-year adjusted *Emission levels*. The difference between the better- and worse-peer effects in *Emission levels* remains statistically significant, with the better-peer effect being 14% larger than the worse-peer effect (Column 2). Moreover, Column 3 and 4 report a statistically significant difference between better-peer and worse-peer effects for *Emission intensity*: The effect of peers with lower *Emission intensity* is 24 times the effect of peers with higher *Emission intensity* (Column 3). When we adjust for sector-year averages, the better-peer effect in *Emission intensity* is seven times the worse-peer effect. These results suggest that firms mainly mimic their better peers, thus indicating that social networks overall serve as a good force in reducing emissions. Furthermore, the results show that the stronger better-peer effect is more pronounced in *Emission intensity* than for *Emission levels*, indicating that firms seem to use *Emission intensity* as the primary metric to benchmark their emission performance against their peers.

Columns 5 and 6 report the results for firms in sectors with high emissions. Specifically, we estimate Eq. (3) using a sample including focal firms in the three NAICS sectors with the highest average firm-year emission levels; (1) Utilities, (2) Transportation and Warehousing and (3) Mining, Quarrying, and Oil and Gas Extraction.[13] In contrast to the full-sample results, we find that firms in these sectors follow peers exhibiting relatively *higher* emissions levels to a larger extent than they follow peers with lower emission levels. The worse-peer effect is significantly stronger than the better-peer effect.[14] However, for *Emission intensity* the pattern among high-emission firms is consistent with the full sample, with the better-peer effect

[12] We get similar result if we control for lagged total revenue of the focal firm and the peer instead of their lagged total assets.
[13] Peer firms may come from other sectors.
[14] We get similar result if we control for lagged total revenue of the focal firm and the peer instead of their lagged total assets.

being significantly stronger. A potential explanation is that high-emission firms may find it more difficult to cut emission levels and instead focus on intensity as their main environmental target. If *Better peers,* in terms of emission intensity, are also *Worse peers* in terms of emission level, this could explain the contrasting results for the two emission variables. Indeed, we find that for focal firms in high-emitting sectors, it is almost twice as likely that the peer firm simultaneously had lower intensity and higher level of emissions, than the opposite combination (in the full sample, both combinations are equally likely). Thus, the more significant worse-peer effect in terms of emission level appears to be an unfortunate by-product of the focus by firms in high-emitting sectors to follow their peers with lower emission intensity.

Overall, these results underscore the significant role of director networks, on average, in driving firms to adopt practices of lower-emitting peers, however with the caveat regarding emission levels in high-emitting sectors.

[Insert Table 4 here]

3.4. Board connectedness and carbon emissions

Thus far, we have focused on the effect of directly related social peers. Next, we investigate the effect of board connectedness in the director network on the emission metrics. To proxy for board connectedness, we estimate the connectedness of each director and then take the average connectedness of all directors on the firm's board. For each director, we construct three commonly used centrality measures and then aggregate them to a single composite measure. *Degree centrality* refers to the number of direct connections. This measure is local because it measures only a director's first-degree connections. *Betweenness centrality* measures the number of shortest paths linking any two individuals that pass through the focal director, divided by the total number of shortest paths existing between any two individuals in the network. Betweenness measures the connections beyond the first neighbors, taking connections of all other individuals in the network into account. Hence, high betweenness centrality should provide information access from various, more distant, parts of the network. *Eigenvector centrality* measures the relative importance of an individual in the network. This measure counts both how many other individuals the director is connected to and the connectedness of these connected individuals.

Because the coverage in BoardEx gradually increases over time, the centrality measures are difficult to compare across periods. To address this issue, we use a relative centrality measure (cf. Amin et al., 2020; El-Khatib, Fogel, & Jandik, 2015). Each year, we assign each director a percentile ranking, based on their degree, betweenness, and eigenvector centralities. The aggregate director-network centrality measure (*Director centrality score*) is defined accordingly:

$$Director\ centrality\ score = \left[\frac{1}{3}\{\text{Percentile}(Degree_i) + \text{Percentile}(Betweenness_i) + \text{Percentile}(Eigenvector_i)\}\right]. \tag{4}$$

Hence, for each director, the aggregate centrality measure, $Director\ centrality\ score$, ranges between 1 and 100, where directors with the highest (lowest) scores are the most (least) connected. To assess board centrality (*Board centrality)*, we then take the average of $Director\ centrality\ score$ of all directors on the firm's board. We then estimate the following panel-data regression model.

$$Emissions_{i,t} = \beta_0 + \beta_1\ Board\ centrality_{i,t-1} + \beta_2 X_{i,t-1} + \beta_3 X_{k,t-1} + \lambda_t + \delta_j + \gamma_k + \varepsilon_{i,t} \tag{5}$$

where $Emissions_{i,t}$ denotes *Emission level* or *Emission intensity* for firm *i* at time *t.* All explanatory variables are lagged by one year to partially mitigate endogeneity concerns. β_1 is the parameter of interest and shows the effect of board centrality at time $t-1$ on the different emissions measures at time *t.* $X_{i,t-1}$ is a vector of firm-level control variables at time $t-1$ and $X_{k,t-1}$ is a vector of country-level control variables at time $t-1$. λ_t are year fixed effects, δ_j are NAICS industry fixed effects, and γ_k are country fixed effects to control for time trends and heterogeneity across industries and countries. We do not control for firm fixed effects as board centrality is relatively stable over time. Instead, we control for unobserved cross-sectional heterogeneity using NAICS industry codes, the most granular industry classification. $\varepsilon_{i,t}$ is the residual term of the regression for firm *i* at time *t.* Standard errors are clustered at the firm level.

Board connectedness may be endogenous, as firms with high emissions, in order to acquire information advantage in emission reduction, could proactively appoint new well-connected directors. To isolate the effect the firms' present directors' connectedness, we follow Amin et al. (2020) and restrict our sample to those firms whose board does not change from the prior year to the current year. Focusing on this sample means that changes in the focal firm's board centrality are exogenous and depend only on other firms' decisions. If boards are able to internalize all forms of information and norms related to emissions reduction, we expect board centrality to have a negative effect on *Emission level* and *Emission intensity.* On the other hand, if board connections facilitate bad norms and practices, board centrality would have a positive effect on the emission variables. The first two columns of Table 5 show that coefficients for *Board Centrality* are insignificant for *Emission level* in the sample of firms across all the sectors with constant board composition from the prior to the current year. This finding holds even when controlling for size (i.e., total assets; Column 1) or total revenue (Column 2). Further, Column 3 shows that the coefficient of *Board Centrality* is insignificant for *Emission intensity.* Moreover, to confirm prior findings of a positive effect of board centrality and the aggregate environmental pillar score (Amin et al., 2021), we estimate Eq. (5) while replacing *Emissions* with Asset4's Environmental pillar score (*E-score)*—the *E* in ESG[15]. The result, reported in Column 4, confirms the positive significant effect of *Board centrality* on *E-score.* A comparison across Columns 1 to 4 shows that firms with well-connected directors do not appear to have lower emissions, though they do appear to have higher environmental scores. On the one hand, our results could be suggestive of greenwashing among firms with well-connected boards as improvements in environmental scores are not accompanied by actual environmental improvements such as reduction emissions reductions. On the

[15] This score consists of 68 individual metrics pertaining to the categories *Resource use*, *Emissions*, and *Innovations*. It considers such aspects as actual emissions (i.e., carbon dioxide and nitrogen and sulfur oxides), waste management, water use, the declaration of emissions-reduction policies, and whether the company develops products or technologies for use in renewable energy (e.g., wind and solar power). According to Asset4, the score is a weighted average of the individual metrics, transformed to a scale from 0 to 100, reflecting a company's percentile ranking within its industry.

other hand, our results could also reflect the ease of transferring information and norms relevant for improving environmental scores and emission reduction through the overall social network. While declaring environmental intentions that constitute environmental scores is relatively less complex, actual emission reduction depends upon complex knowledge and skill development (Hart, 1995, Miles, Munilla, and Darroch, 2006). In line with these considerations, while overall board connectedness can facilitate a search for new knowledge and information regarding environmental scores, directors might have difficulties internalizing more specific, complex knowledge for emission reduction and using it to their firms' benefits. While we cannot rule out either of the explanations, our results from the peer-effects analysis underscore the role of direct social links in driving carbon emission reductions, in line with the notion that more complex information and norms are more easily transmitted through direct, close ties (Uzzi, 1999).

Column 5 to 8 of Table 5 report the results in the subsample of firms with constant board composition in high-emitting sectors. Column 5 shows that the coefficient of board-director centrality is positive and significant for *Emission levels*. However, this is due to firms' revenue influencing both centrality and *Emission levels*, since the coefficient of centrality becomes insignificant when we control for lagged log of total revenue (Column 6). Furthermore, similar to the overall sample, board centrality has no significant effect on *Emission intensity* for high-emissions companies (Column 7). The positive effect of board centrality on *E-score* is confirmed also in the subsample of firms high-emitting sectors (Column 8). In summary, the influence of board centrality in high-emitting sectors is similar to its influence in other sectors.

[Insert Table 5 here]

4. Conclusion

This paper investigates the role of board directors' social-network connections on firms' carbon emissions. We find causal propagation effects of carbon-emissions levels and emission intensity among socially connected companies. The peer effect is primarily driven by firms mimicking peers with relatively lower emissions (*better peers*) rather than peers with higher emissions (*worse peers*). However, for firms in high-emitting sectors, the focus to follow peers with lower emission intensity seems to lead to an unintended consequence–a stronger *worse peer* effect in terms of emission levels. This suggests that firms tend to use emission intensity as the primary metric to benchmark their emission performance against their social peers and that the focus on intensity backfires in high-emitting sectors. This points to a caveat regarding the role of social network propagation since Net Zero Carbon pledges are about reducing absolute emissions rather than emission intensity.

Focusing on board connectedness, we find no evidence of causal effect on either emission level or emission intensity in the overall sample nor in the high-emitting sectors, which points to limited advantages of board connectedness for carbon emission reductions. Our findings do however confirm a positive effect of board centrality on aggregate environmental pillar score, potentially suggesting a greenwashing behavior. Collectively, our results point to the limits of board directors' social networks in shaping firm environmental performance, particularly in high-emitting sectors.

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Table 1 Summary statistics

This table reports the main variables' summary statistics. *Emission level* is the log of Scope 1 plus Scope 2 CO_2 emissions in tons and *Emission intensity* is Scope 1 plus Scope 2 CO_2 emissions divided by revenue in USD million. *Board size* is the number of directors on the board, *Board diversity* is the proportion of women on the board, *Board independence* is the proportion of independent directors on the board, *Board tenure* is the average tenure of board directors, and *Board age* is average age of board directors. *Size* is the logarithm of total assets, *Leverage* is long- and short-term debt over total assets, *Tobin's Q* is the market-to-book equity ratio, *RoA* is return on assets, *Cash ratio* is the ratio of cash to the book value of total assets, and *CEO duality* is equal to 1 if the CEO also chairs the board. *GDP per capita* is in USD thousand, and *CO_2 to GDP* is CO_2 emissions in kilograms per PPP$ of GDP. *Emission intensity* is winsorized at 2.5% from both sides. Other firm-level variables are winsorized at the 1st and 99th percentiles. The sample covers the period 2004–2020.

	Mean	St dev	Minimum	Median	Maximum	Obs.	#Firms
Emission level	12.420	2.597	10.773	12.395	14.113	19,048	3,304
Emission intensity	3.568	8.043	0.164	0.498	2.723	19,048	3,304
Board size	11.626	3.871	9	11	13	19,048	3,304
Board diversity	0.172	0.121	0.091	0.167	0.250	19,048	3,304
Board independence	0.621	0.249	0.462	0.667	0.833	19,048	3,304
Board tenure	7.164	3.114	5.000	6.714	9.000	19,048	3,304
Board age	59.770	4.208	56.900	59.846	62.750	19,048	3,304
Size	22.684	1.512	21.642	22.633	23.674	19,048	3,304
Leverage	0.254	0.165	0.130	0.245	0.359	19,048	3,304
Tobin's q	3.286	4.002	1.265	2.108	3.668	19,048	3,304
RoA	5.290	7.290	2.111	4.732	8.379	19,048	3,304
Cash ratio	0.074	0.081	0.019	0.049	0.100	19,048	3,304
CEO duality	0.906	0.292	0	1	1	19,048	3,304
GDP per capita	10.591	0.621	10.608	10.746	10.908	19,048	3,304
CO2 to GDP	0.249	0.119	0.155	0.242	0.313	19,048	3,304

Table 2: Propagation of foreign emission regulations through director networks

This table reports the DiD estimates of foreign peer firms' exposure to emissions regulation on focal firm's emissions. The dependent variables in Columns 1 and 2 are focal firm's *Emission level* and *Emission intensity*, respectively. *Regulation* takes the value one if a regulation is imposed in the peer firm's country and retains that value in subsequent years. The models include one-year lagged control variables. Variables are described in Section 2 and in Appendix A.1. Both specifications include cohort-firm and cohort-year fixed effects. Standard errors are clustered at the firm level. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)
	Emission level	*Emission intensity*
Regulation	-0.0899***	-0.219*
	(0.0257)	(0.125)
Board size	-0.00112	-0.0117
	(0.00135)	(0.00810)
Board diversity	-0.171***	-0.507*
	(0.0520)	(0.286)
Board independence	0.128**	-0.421
	(0.0512)	(0.267)
Board tenure	0.00207	0.0567**
	(0.00376)	(0.0241)
Board age	0.0116***	-0.00805
	(0.00239)	(0.0126)
Size	0.437***	-0.547***
	(0.0217)	(0.153)
Leverage	-0.148***	1.107**
	(0.0543)	(0.449)
Tobin's q	0.00117	-0.0239***
	(0.00155)	(0.00627)
RoA	-0.000343	-0.0200***
	(0.000723)	(0.00515)
Cash ratio	-0.514***	-2.450***
	(0.115)	(0.694)
CEO duality	0.0441**	-0.154
	(0.0200)	(0.0998)
GDP per capita	-0.250***	-0.143
	(0.0610)	(0.419)
CO2 to GDP	0.940***	9.420***
	(0.356)	(2.032)
Constant	4.230***	16.29***
	(0.886)	(5.751)
Cohort-firm FEs	Yes	Yes
Cohort-year FEs	Yes	Yes
Observations	51,331	51,331
R^2	0.983	0.948

Table 3. Directors' social-connection effects in connected and unconnected relationship periods

This table reports the regression estimates with the focal firm's emissions as the dependent variable. The dependent variables in Columns 1 and 2 are the focal firm's *Emission level* and *Emission intensity*, respectively. The independent variable is the one-year lagged corresponding peer company variable (*Emission_P*). The estimation is based on the sample including the unconnected relationships. *Connected* (*Unconnected*) is an indicator equal to one (zero) for the connection period of each firm pair and zero (one) otherwise. The *p*-value is for the test of the hypothesis that the coefficient of the interaction term with *Connected* (A) and *Unconnected* (B) are equal. The models include one-year lagged control variables for both focal and peer companies. Variables are described in Section 2 and in Appendix A.1. Both specifications include firm-pair and year fixed effects. Standard errors are clustered at the firm-pair level and are shown in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1) *Emission level*	(2) *Emission intensity*
A: *Emission_P* × *Connected*	0.0120***	0.0055***
	(0.0019)	(0.0018)
B: *Emission_P* × *Unconnected*	0.0010	0.0010
	(0.0017)	(0.0015)
P-value (H0: A = B)	0.0000	0.0557
Focal firm controls	Yes	Yes
Peer firm controls	Yes	Yes
Pair FEs	Yes	Yes
Year FEs	Yes	Yes
Observations	1,847,712	1,847,712
R^2	0.9865	0.9612

Table 4: Effects from better- and worse-performing peers on *Emission level* and *Emission intensity*

This table reports the regression estimates with focal firm's emissions as dependent variable. In Columns 2 and 4, all variables are sector-year adjusted. The dependent variables in Columns 1 and 2 is the focal firm's *Emission level*. The dependent variables in Column 3 and 4 is the *Emission intensity*. Columns 5 and 6 report the results in a subsample of firms in high-emitting sectors. The independent variable is the one year lagged corresponding variable for the peer company (*Emissions_P*). *Better* (*Worse*)*_peer* is an indicator taking the value one (zero) if the peer firm has a lower (higher) *Emission level* or *Emission intensity* than the focal firm. The *p*-value is for the test of the hypothesis that the coefficients of the interaction term with *Better_peer* (A) and *Worse_peer* (B) are equal. The models also include one-year lagged control variables from both the focal and peer company. Variables are described in Section 2 and in Appendix A.1. All specifications include firm-pair and year fixed effects. Standard errors are clustered at the firm-pair level and are shown in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	All sectors				High-emitting sectors	
	(1)	(2)	(3)	(4)	(5)	(6)
	Emission level	*Emission level*	*Emission intensity*	*Emission intensity*	*Emission level*	*Emission intensity*
A: *Emissions_P* × *Better_peer*	0.0491***	0.0727***	0.2179***	0.1088***	0.0337***	0.1885***
	(0.0023)	(0.0024)	(0.0144)	(0.0077)	(0.0046)	(0.0214)
B: *Emissions_P* × *Worse_peer*	0.0388***	0.0636***	0.0092***	0.0154***	0.0536***	0.0184***
	(0.0027)	(0.0027)	(0.0018)	(0.0023)	(0.0083)	(0.0069)
P-value (H0: A = B)	0.0006	0.0055	0.0000	0.0000	0.0172	0
Sector-year adjusted	No	Yes	No	Yes	No	No
Focal firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Peer firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Pair FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	919,082	919,082	919,082	919,082	164,612	164,612
R^2	0.9877	0.9784	0.9655	0.9512	0.9848	0.9505

Table 5. Effects of board connectedness on environmental performance variables

This table reports regression estimates of *Emission level*, *Emission intensity, and E-score* on *Board centrality* in the full sample and in a subsample of high-emitting sectors. The sample includes firms with constant boards (firms whose boards do not change from the prior year to the current year). *Board centrality* is the average of the board of directors' *Director centrality score,* which in turn is the average of a director's percentile ranking in degree, eigenvector, and betweenness centrality. The models also include one-year lagged control variables. Variables are described in Section 2 and Appendix A.1. All specifications include year, industry, and country fixed effects. Standard errors are clustered at the firm level and are shown in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	All sectors				High-emitting sectors			
	(1) *Emission level*	(2) *Emission level*	(3) *Emission intensity*	(4) *E-score*	(5) *Emission level*	(6) *Emission level*	(7) *Emission intensity*	(8) *E-score*
Board centrality	0.0055	-0.0006	−0.0074	0.1723***	0.0150***	0.0019	0.0671	0.1486***
	(0.0034)	(0.0034)	(0.0157)	(0.0434)	(0.0070)	(0.0075)	(0.0329)	(0.0578)
Size	0.8480***		-0.3861*	6.6504***	0.7572***		-1.8630***	7.5522***
	(0.0414)		(0.2045)	(0.6016)	(0.0947)		(0.6076)	(0.9854)
Log(Revenue)		0.9541***				0.9431***		
		(0.0391)				(0.0742)		
Firm controls	Yes		Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes		Yes	Yes	Yes	Yes	Yes	Yes
Industry FEs	Yes		Yes	Yes	Yes	Yes	Yes	Yes
Country FEs	Yes		Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,069	3,065	3,069	3,069	642	642	642	642
R^2	0.8121	0.8362	0.6242	0.5243	0.7124	0.7657	0.5839	0.6191

Appendix

Table A1. Variable definitions

This table defines the variables and indicates the data sources.

Variable	Definition
Emissions	
Emission level	The logarithm of the sum of direct (Scope 1) and indirect (Scope 2) carbon emissions in tons. Source: Asset4
Emission intensity	The sum of direct (Scope 1) and indirect (Scope 2) carbon emissions in tons per USD million of revenue. Source: Asset4
Firm characteristics	
Board size	The number of directors on the board. Source: BoardEx
Board diversity	The proportion of women on the board. Source: BoardEx
Board independence	The proportion of independent directors on the board. Source: BoardEx
Board tenure	The average tenure of board directors. Source: BoardEx
Board age	The average age of board directors. Source: BoardEx
Director centrality score	The average of a director's percentile ranking in degree, eigenvector, and betweenness centrality.
Board centrality	The average of a firm's the board of directors' *Director centrality score*
Size	The logarithm of total assets. Source: Eikon
Leverage	The ratio of long- and short-term debt to the book value of total assets. Source: Eikon
Tobin's Q	The market value of equity divided by the book value of equity. Source: Eikon
RoA	Income after taxes for the fiscal period divided by the average of year-beginning and -end total assets. Source: Eikon
Cash ratio	The ratio of cash to the average of year-beginning and -end total assets. Source: Eikon
CEO duality	Dummy variable equal to one if the CEO also chairs the board. Source: BoardEx
Revenue	Revenue from all of a company's operating activities deducting any sales adjustments and their equivalents. Source: Eikon
Connected	Dummy variable equal to one for the period when two firms are connected through one or more directors' social contact and zero otherwise. Source: BoardEx
Unconnected	Dummy variable equal to one for the period when two firms are not connected through one or more directors' social contact and zero otherwise. Source: BoardEx
Better peer	Dummy variable equal to one if the peer firm exhibits better environmental performance than the focal firm and zero otherwise. Source: Asset4
Worse peer	Dummy variable equal to one if the peer firm exhibits worse environmental performance than the focal firm and zero otherwise. Source: Asset4
Regulation	Dummy variable equal to one if a new regulation related to emissions has come into effect in the peer firm's country. Source: Carrots & Sticks
Country characteristics	
GDP per capita	GDP per capita in current USD thousand (logged). Source: World Bank
CO2 to GDP	Kilograms of CO_2 emissions per PPP$ of GDP. Source: World Bank

Table A2. Mandatory Emissions regulations and reporting globally

This table shows mandatory emissions regulations and reporting globally for the period 2003–2020. The data are obtained from the Carrot & Sticks reports.

Country	Year	Title	Description
Australia	2008	National Greenhouse and Energy Reporting Regulations	Regulations that establish compliance rules and procedures for administering the National Greenhouse and Energy Reporting Act, 2007
	2011	Carbon Credits (Carbon Farming Initiative) Act	Act to implement obligations that Australia has under the Climate Change Convention and the Kyoto Protocol
Austria	2011	Emission Certificates Act 2011—EZG 2011	Federal law on a system for trading in greenhouse-gas emission certificates
Brazil	2012	Board Decision 254	Criteria for preparing the inventory of greenhouse-gas emissions
	2014	Board Decision 82	Extension of the deadline for the delivery of the inventory of greenhouse-gas emissions
	2015	Board Decision 125	Extension of the deadline for the delivery of the inventory of greenhouse-gas emissions
China	2012	Cleaner Production Promotion Law	Decision to avoid, for example, the generation of pollutants
	2013	Pollution Source Monitoring Notice	Notice to establish and improve pollution-source monitoring and information disclosure
	2016	Environmental Protection Tax Law	Law to protect and improve the environment, reduce pollutant emissions, and promote the construction of ecological civilization
	2017	Carbon Emission Trading Market Construction Plan	Plan to establish a carbon-emissions-rights trading market
Czech Republic	2008	Government Regulations on Establishing a List of Pollutants	Regulation to establish a list of pollutants required for reporting to the Integrated Register of Environmental Pollution
	2012	Act on air protection	Act defining objectives for air quality: air protection, the prevention of air pollution, and reducing the level of pollution
Denmark	2003	Order on the Limitation of Certain Air Pollutants Emissions from Large Combustion Plants	Regulation aiming to limit certain air pollutants emitted from large combustion plants
	2012	CO_2 quotas law	Act obligating businesses that operate in Denmark and are included in the EU Emissions Trading System to hold CO_2 quotas equal to their annual emissions of greenhouse gases
Finland	2011	Emissions trading act	Law to promote the reduction of greenhouse-gas emissions in an economical manner
	2013	Decree on the Monitoring and Reporting of Greenhouse Gas Emissions	Regulation providing for monitoring and reporting of greenhouse-gas emissions
	2014	Environmental Protection Act 527	Act to prevent the pollution of the environment
France	2010	Code de l’Environnement, Livre II, Titre II, Art L229-25	Requiring disclosure of Scope 1 and 2 greenhouse-gas emissions
	2015	French Energy Transition Law, Art 173	Requiring disclosure of financial risks due to climate change
Germany	2011	Greenhouse Gas Emissions Trading Act	Act on trading in allowances for the issuance of greenhouse gases

Country	Year	Title	Description
Hungary	2010	Government Decree on the Requirements and Verification of Sustainable Biofuel Production	Promotion of the use of renewable energy for transport purposes and the reduction of greenhouse-gas emissions from energy used in transport
Israel	2012	Environmental Protection Law	Law to report pollution with the central Pollutant Release and Transfer Register
Japan	2005	Mandatory GHG Accounting System	Requirement to disclose GHG emissions
Kenya	2014	Environmental Management and Co-ordination Act	Regulation of air-pollution standards, measurement, and licenses
Mexico	2016	General Climate Change Law	Law covering regulation of emissions of gases and greenhouse-effect compounds
New Zealand	2019	Climate Change Response (Zero Carbon) Amendment Act	
Norway	2014	Greenhouse Gas Trading Act	Act to limit emissions of GHGs in a cost-effective manner
Philippines	2006	Biofuels Act	Act to promote development and utilization of renewable energy sources to mitigate toxic and greenhouse-gas emissions
Poland	2009	Act on the Management of Greenhouse Gases and Other Substances	Act establishing principles to limit greenhouse-gas and other substance emissions under the Kyoto Protocol
Russia	2018	State Regulation on Emissions	Regulation to create conditions for reducing greenhouse-gas emissions
South Africa	2004	Air Quality Act 39	Act to regulate air-quality and provide measures for the prevention of pollution and ecological degradation
Spain	2005	Law 1/2005 on Trading System for Greenhouse Gas Emission Rights	Law to implement and maintain a monitoring system of greenhouse-gas and to submit an annual report
Spain	2007	Law 34/2007 on Air Quality and Protection of the Atmosphere	Law to establish air-quality standards for major pollutants and to create a framework for enforcement of Spanish environmental law
Spain	2014	Decree on Creating the Carbon Footprint Registry	Creation of the carbon-footprint register, compensation, and CO_2 absorption projects
Spain	2020	Law 9/2020 on the Trading Regime of Greenhouse Gas Emission Rights	Law on the trading regime of greenhouse-gas-emissions rights
UK	2008	Climate Change Act	Act to ensure that the UK accounts for all six Kyoto gas groups
	2010	The CRC Energy Efficiency Scheme Order 2010. 2010 No. 768	Commitment requiring companies to measure and report on all their emissions-related energy use to the Environment Agency
	2013	The Companies Act	Act requiring all UK companies to produce a standalone Strategic Report including reporting on greenhouse-gas emissions
US	2009	40 CFR Parts 86 87 89 Final Rule on Mandatory Reporting of Greenhouse Gases	Regulation requiring reporting of greenhouse-gas emissions
	2010	17 CFR Parts 211, 231 and 241 Commission Guidance Regarding Disclosure Related to Climate Change	SEC disclosure requirements as they apply to climate-change matters