Does the duration of team governance decrease corporate carbon emission intensity

----Evidence from 608 U.S. listed corporations in 2009-2018

Abstract: The study explores the effects of duration of team governance (DTG) on carbon emission intensity of 608 U.S. listed corporations merged three official datasets of Carbon Disclosure Project (CDP), Compuatat and BoardEx over the period 2009-2018, using unbalanced panel data analysis. It bridges three theoretical approaches: group development theory (GDT), social identity theory (SIT) and resource dependence theory (RDT) and applies econometric analysis techniques to investigate corporate carbon emission intensity. The result shows an inverted U-shaped relationship between DTG and carbon emission intensity. It is interesting that carbon emission intensity increased when the duration is less than 6.52 years, however, the duration exceeds 6.52 years decreases carbon emission intensity. We also find other factors of team size and gender diversity moderate the U-shaped relationship, further testing the optimal team of 8-11 members and 3-4 women members. Meanwhile, the finding shows that the low-carbon innovation is an effective mediator for DTG to decrease carbon emission intensity. The paper is important for managerial implication and policy making.

Keywords: group development theory; social identity theory; resource dependence theory; unbalanced panel data analysis; duration of team governance; carbon emission intensity

Introduction

Human activities emit a considerable amount of greenhouse gases (GHGs), to which industrial production contributes the most. Corporations, as major emitters of GHGs, have an obligation to take on the growing global climate change problem (World Economic Forum, 2020). Corporate stakeholders, such as customers or investors, are beginning to focus on a corporate performance in terms of its social and environmental dimensions (Sarkis et al. 2010). To balance profits while reducing GHG emissions, more and more corporations have incorporated environmental performance into their performance measures. Corporations view sustainability and environmental performance as necessary strategies. Carbon emission reduction is the main index to measure corporate environmental performance, which has direct and indirect impacts on their profits (New York Times, 2019).

Under the influence of global warming, extreme weather occurs frequently. The blow to the United States by the climate problem is enormous. High temperatures and heat waves have climbed temperatures in the United States and surrounding areas by nearly 50 degrees Celsius, and California has even reached 54.4 degrees Celsius (Vornicu, 2021). According to statistics, the total CO_2 emissions of the United States are 4,981,300 kt from 1990 to 2018 and rank the first in the world (Polat et al., 2022). The United States urgently needs to shoulder its great power responsibility for addressing climate change. Despite the impact of climate change on the United States, the federal government does not appear to have much support for efforts to reduce CO_2. They are unwilling to hold back the economy by reducing carbon emissions. Therefore, carbon emissions reduction in the United States is more like market-based incentives and voluntary actions. The voluntary carbon reduction actions that U.S. corporations rely on are consistent with our data sources. Our data comes from the CDP database, a carbon emission reduction questionnaire that relies on voluntary corporate disclosures. Therefore, choosing U.S. corporations makes our research findings more credible.

In previous studies, most scholars focus on the influence of individual managers on corporate social responsibility (CSR) and sustainable development (social performance), such as CEO (Hossain et al., 2022; Al-Shaer and Zaman, 2018; Walls and Berrone, 2017), chief sustainable officer (CSO) (Fu et al., 2020; Kanashiro and Rivera, 2019), chief executives of CSR (Wiengarten et al., 2017; Strand, 2013), chief financial officer (CFO) (Profitlich et al., 2021; Velte and Stawinoga, 2020; Wiengarten et al., 2017), chief information officer (CIO) (Chan, 2021) and chief operating officer (COO) (Menz, 2012). Nowadays, teams gradually replacing individuals become an effective way for organizations to respond to change and achieve organizational performance (Lacerenza et al., 2018; Sanyal and Hisam, 2018; Kozlowski and Bell, 2013; Salas et al., 2004). Team governance is playing a leading role in decision-making and has become a new way for corporations to improve performance and solve complex problems (Salas et al., 2018). Due to the complexity of corporate emission reduction activities, most decisions are no longer made solely by managers individually (Haque, 2017). Increasingly, corporations are starting to create internal positions of climate change leaders, and prefer to appoint teams to be responsible for carbon reduction activities within their organizations (CDP, 2019). Special committees voluntarily established by corporations, such as the environmental committee and the corporate social responsibility committee, reflect the attitude of corporations toward the responsibility to control carbon emissions (Liao et al. 2015). The existing literature explores the impact on corporate sustainability and environmental performance from the board perspective (Konadu et al., 2022; Nuber and Velte, 2021; Ben-Amar et al., 2017), but no scholar has considered it from a team perspective. However, the implementation of teams in organizations is not always successful (Allen and Hecht, 2004).

According to group development theory, group development goes through counter dependence and fight, trust and structure, work and termination five stages (Chang et al., 2003), namely the two stages of conflict and integration. At the early stage of teams, team members self-categorize into different groups due to their values, experiences and other characteristics. Team governance is a kind of cooperative behavior, which needs members to identify with others. However, the differences in members' identities will lead to conflicts, which cause failure (Bochatay et al., 2019). When teams grow to a certain period, a high sense of team identity increases trust and decision-making efficiency among members (Rezaei et al., 2020). Social identity theory explains the interplay between conflict and integration in teams. Thus, we argue effective team requires a duration of medium and above (Abrantes et al., 2020). The team governance considered in this paper is oriented to the corporate carbon emission reduction task. There are uncertain empirical results on how the expertise of boards and committees is used in these teams to address corporate carbon reduction and sustainability issues, which is worth our research.

Beyond a potential theoretical explanation, whether the relationship is positive or negative typically depends on certain moderators (team size and gender diversity) (Dawson et al., 2022; Poletti-Hughes and Martinez Garcia, 2022; Kabore et al., 2021; Lauring and Villesèche, 2019; Li, 2018; Ruiz-Jiménez et al., 2016; Backes-Gellner et al., 2015; Vaccaro et al., 2012) .Based on social identity theory, team size is viewed as a critical boundary condition for affecting team partnership (Sui et al., 2016; Levine and Crowther, 2008) and a pivotal characteristic shaping internal team dynamics (Stewart, 2006). the similarity between women members brings more interaction and cooperation. Gender diversity is one of the key factors determining team effectiveness by influencing the internal member relationship. Thus, we argue that duration of team governance (DTG) can have both positive and negative effects on corporate performance depending on certain contextual conditions. Besides, low-carbon innovation is determined the effective of corporate carbon emission actions. Based resource dependence theory, corporations with more resources are conductive to achieve this the carbon emission reduction channel. From the perspective of board committees, this paper explores the relationship between DTG and corporate carbon emissions and the moderating effect under certain contextual conditions and further find out an effective channel.

Our study makes some contributions to the literature review. Firstly, we innovatively verify a U-shaped relationship to fill in the gap in the existing group development theory. Our results provide managerial implications for corporations that teams need a DTG of medium or above to be effective in their responsibility to reduce carbon emissions. Secondly, we illustrate the impact of team size and gender diversity on corporate carbon emission intensity. Based on the group development theory, we enrich the impact of teams on corporate carbon emission intensity in different contexts of social identity theory. Our results suggest that team size and gender diversity have a positive influence on decrease corporate carbon emission intensity, but it is not always beneficial. At least in terms of climate change teams, team size and gender diversity have the optimal number of members. Thirdly, we explore a channel for DTG to decrease corporate carbon emission intensity. Underpinned by RBV, we argue that duration of Team Governance (DTG) results in a greater low-carbon innovation and this in turn leads to lower carbon emissions.

The remainder of the paper is organized as follows. Section 2 describes current status of climate change and carbon emissions reform in the United States Section. 3 provides a conceptual framework for DTG and its relationship with corporate carbon emission intensity. Section 4 describes the data and methods used in this study. Section 5 reports the empirical results and discussion. Section 6 concludes this study.

Conceptual framework

DTG and corporate carbon emission intensity

Existing literature on team development and effectiveness highlights the critical relevance of DTG (Gonzalez-Mulé et al., 2020). While still paling in comparison to research on individual governance, scholars have become increasingly interested in DTG (Walls et al., 2012). We use group development theory to explain why the impact of DTG may sometimes be positive and other times negative. Group development theory refers to the process of achieving team effectiveness in the process of team growth. Koopmann et al. (2016) argue that team tenure has a curvilinear influence on team interpersonal dynamics. In team development, team members have both antagonistic and interdependent relationships. Most of the empirical research examining the impact of different interpersonal relationships between members on team development (Olie et al., 2020; Kammerhoff et al., 2019; Bell et al., 2011). Therefore, conflict and integration are the inevitable process of team development. Team members' identity is greatly influenced by their personal experiences, values, and personalities (Samimi et al., 2020). Early team members are unable to judge the trustworthiness of their teammates, and the differences among members make them experience low-quality interpersonal interaction with teammates, leading to team conflict (Adamovic, 2020). Team conflict decreases cooperation and understanding among team members, leading to a low governance performance (Bui et al., 2019). With the increase of DTG, the commitment and ability of team members will be strengthened (Chen et al., 2019). Team members will be less susceptible to pressure from managers and peers, and more likely to limit opportunistic managerial behaviors (Boivie et al., 2021). A longer DTG provides team members with more time to work on tasks or interpersonal relationships, and gain mutual understanding and trust between each other (Delizonna, 2017). Their experience and resources can also be better integrated into team decision-making to make team decision-making more efficient.

Team size and corporate carbon emission intensity

Based on social identity theory, team size affects team partnership (Sui et al., 2016; Levine and Crowther, 2008), and shapes internal team dynamics characteristics (Stewart, 2006). Team members aid corporate performance by their own particular expertise, whether it is knowledge, skills or interpersonal relationships. Thus, large teams have access to more unique resources, which helps corporations to accomplish specific team tasks such as reducing corporate carbon emissions (Forbes et al., 2006). Backes-Gellner et al. (2015) argue that building on study from the lifecycle literature, there obviously appears to be a nonlinear relationship between team size and performance. Larger, rather than smaller, teams can make members more actively express their own unique perspectives and prevent the team from making one-sided decisions. Based on resource dependence theory, larger teams are also more likely to facilitate access to critical financial resources, and have more financial leeway to pursue environmental initiatives (De Villiers et al., 2011). On the contrary, large teams are more likely to have disagreements over firm strategy resulting in increased coordination costs for resolving these disagreements. Team members exhibit less dependence on competition and become free riders. They are more likely because of similar characteristics of members to form sub-teams, causing internal faultlines (Antino et al., 2019).

Gender diversity and corporate carbon emission intensity

Gender is a basis for team categorization and is often used to explain differences and behaviors among members (Chattopadhyay et al., 2004). Members categorize one other on the basis of gender similarity when the team is being formed (Harris et al., 2014; Van Knippenbery et al., 2004). Based on social identity theory, both men and women are preferring the same-sex as colleagues (Terjesen and Sealy, 2016). Liao et al. (2015) argue that women directors are more likely to be assigned to boards and to accept roles related to environmental and sustainability matters. Due to women care more about quality of life, and they are more sensitive to environmental issues (Hofstede, and Minkov, 2010). Considering the arguments of resource dependence theory, gender diversity improves the ability of teams to integrate, reconfigure and accumulate resources. Women emphasize the welfare of all rather than self-interest, and they are more likely to take emissions reduction initiatives and reduce corporate carbon emission intensity (Saeed et al., 2021; Taylor and Hood, 2011). Gender diversity improves the quality of team discussions, and holds management accountable for performance more firmly than their men counterparts (Boone and Hendriks, 2009). We argue that in teams with higher gender diversity, team decision-making will be more inclined to pay attention to environmental issues and are more likely to obtain good results in terms of corporate environmental performance. Increased gender diversity can create disagreements between men and women members and make women seen as competitors (Hsu and Lawler, 2019; Yang and del Carmen Triana, 2019). This bias will affect women's decision-making ability and reduce decision-making performance.

Low-carbon innovation and corporate carbon emission intensity

Under a wave of global environmental protection, environmental management has become a vital factor in corporate development (Knight et al., 2019). In order to meet the expectations of stakeholders and consumers, teams begin to take innovative actions to reduce the corporate carbon emission intensities. Corporate strategies and initiatives are investing in green management to improve their environmental behavior (He et al., 2019). Teams as the primary unit for developing new innovations, are expected to exert some positive force toward team's innovation behavior (Markham and Lee, 2014; Hülsheger et al., 2009). A significant body of research suggests some type of psychological attachment of individuals to their teams is beneficial to innovation on average (Litchfield et al., 2018). In order to adapt to the changing environment, team members reflect on their processes and strategies in the task environment to achieve goals, which is more likely to generate innovative behavior to achieve performance (Covin et al., 2020). Although team identity has behavioral consistency with team creativity, a strong team identity alone provided little indication that innovative behavior will be motivated (Litchfield et al., 2018). Social identity theory argues that in order to gain high recognition in teams, team members will act in accordance with the recognition of the team psychologically and less likely to propose different ways of doing things. Ancona and Caldwell (1992) propose “isolationist” teams identified, which argue team bonds may fail to encourage innovative behavior. We argue that team members exhibit particularly complex influences on innovative behavior (Glynn et al., 2010).

In Fig. 1, we propose the theoretical framework.

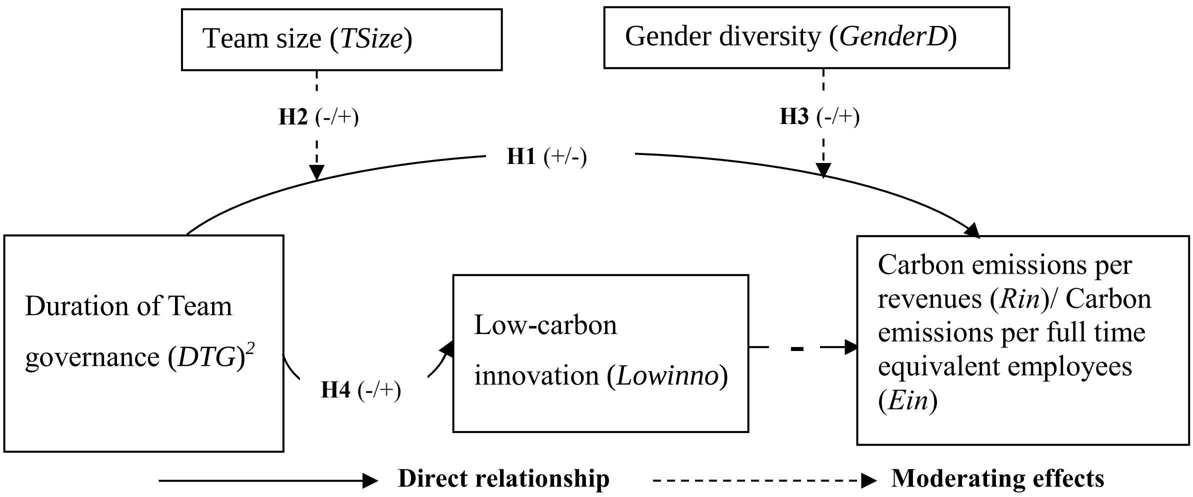

Fig. 1. Theoretical framework
Source: Combine by authors.

Hypotheses Development

DTG and carbon emission intensity

In the early stages of DTG, due to fewer new ideas and lower efficiency and sensitivity to information processing. The complex team tasks make team members impossible to rely on their limited knowledge and experience to solve the overall goals of the team (Greer et al., 2018). Conflicts caused by members' differences can lead to lower team governance effectiveness (Thiel et al., 2019). Meanwhile, conflicts will also make team members adjust to achieve harmony and gradually form a unified working state. As DTG increases, the sense of cohesion and trust between team members and makes them gradually tend to form unified and effective team decisions. Team trust can suppress emotional conflicts and facilitate the formation of beneficial conflict patterns within the group. A high degree of identity makes team effectiveness will be greatly improved (Shan et al., 2021; Ambrose et al., 2018). Therefore, we propose the following hypothesis. For the details. Please see fig. 2.

Hypothesis 1: There is an inverted U-shaped relationship between DTG and corporate carbon emission intensity.

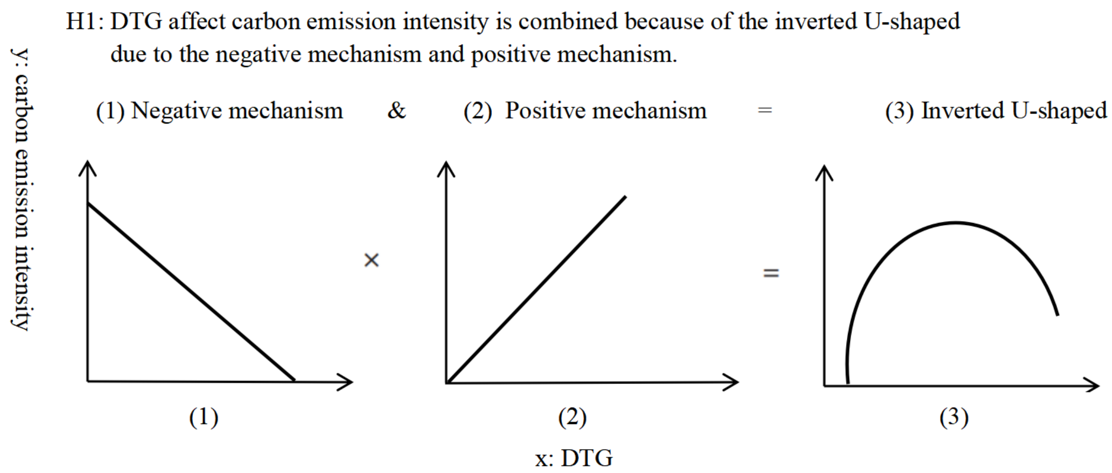

Fig. 2. Latent mechanism of the inverted U-shaped relationship.

The moderating role of team size

Based on social identity theory and resource dependence theory, large teams have greater cognitive resources and shared information at their disposal that provides more perspectives for team decision-making to improve corporate performance (Aggarwal and Woolley, 2019). In contrast, smaller teams are less likely to benefit from team resources and shared information because resources are not comprehensive. At a short DTG (namely, the upward trend of the hypothesized inverted U-shaped curve), the positive DTG-corporate carbon emission intensity relationship is likely to be stronger for larger, rather than smaller, team size.

When possesses longer DTG in larger teams, large teams are also more likely to make coordination and communication more tedious, have disagreements over firm strategy (Liang et al., 2008), have weak internal competitiveness, bring the possibility of free-riding by individual members of the team, causing internal faultlines (Antino et al., 2019). In contrast, smaller team members have fewer coordination problems, they can form greater cohesion and a strong sense of interdependence (Marques-Quinteiro et al., 2019). Smaller teams have less competition and friction, which have lower costs input and shorter run-in times. At a long DTG (namely, the downward trend of the hypothesized inverted U-shaped curve), the negative DTG-corporate carbon emission intensity relationship is likely to be weaker for larger, rather than smaller, team size. Therefore, team size moderates the inverted U-shaped relationship by shifting the turning point to the left (see Fig. 3).

Further, we argue that there should have an optimal team size. an increase in size above a context-specific maximum may increase coordination problems and unequal participation of group members (Greer et al., 2018). The question of the optimal group size has been concerned by scholars, who propose that 4-10 team members is optimum. Therefore, we propose the following hypothesis:

Hypothesis 2: Team size has a positive moderating effect at the left of the turning point, has a negative moderating effect at the right of the turning point and exist an optimal team size.

The moderating role of gender diversity

Based on social identity theory and resource dependence theory, the similarity between women members brings more interaction and cooperation， improves the status and discourse power of women in the team (Pullen and Vachhani, 2021). Gender diversity increases the ability of teams to acquire and accumulate resources that are more relevant to corporate environment and sustainability. Women express greater concerns for the environment than their men counterparts, and they are more likely to engage in pro-environmental activities and make a positive contribution to sustainable development (Haque, 2017). At a short DTG (namely, the upward trend of the hypothesized inverted U-shaped curve), the positive DTG-corporate carbon emission intensity relationship is likely to be stronger for higher, rather than lower, gender diversity.

In a long DTG, increased gender diversity can lead to team members' decreased communication (Kravitz, 2003), increase differences and conflict (van den Oever and Beerens, 2021), lack of cohesion (Wahid, 2019) and cooperation (Chatman and Flynn, 2001). The aged men members may see themselves in the same social category that is characterized by maturity and experience while women may be perceived as "others" who are not mature or experienced. At a long DTG (namely, the downward trend of the hypothesized inverted U-shaped curve), the negative DTG-corporate carbon emission intensity relationship is likely to be weaker for larger, rather than smaller, gender diversity. Therefore, gender diversity moderates the inverted U-shaped relationship by shifting the turning point to the left (see Fig. 3).

Further, we argue that only when women make up a certain number in a group, their presence is valued. Critical mass is attained with three women or more (Chen and Houser, 2019; Cabeza-García et al., 2018; Ben-Amar et al., 2017). Therefore, we propose the following hypothesis:

Hypothesis 3: Gender diversity has a positive moderating effect at the left of the turning point, has a negative moderating effect at the right of the turning point and exist an optimal number of women members.

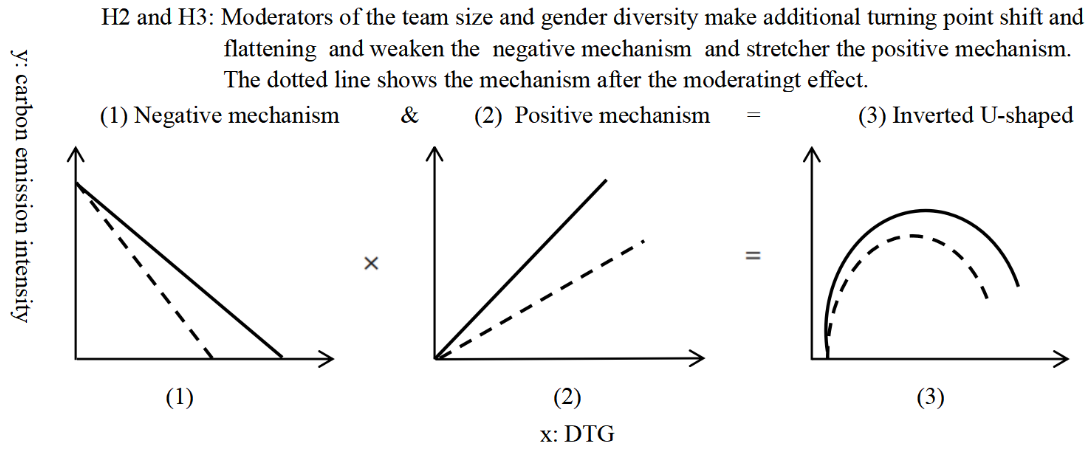

Fig. 3. Moderating effect of the inverted U-shaped relationship.

Mediation of low-carbon innovation

Inspired by Wang et al. (2016), low-carbon innovation as a mediator of DTG and corporate carbon emission intensity curvilinear relationship would be theoretically meet the support of three main effects: (a) an inverted U-shaped relationship between DTG and corporate carbon emission intensity (the same with H1); (b) a U-shaped relationship between DTG and low-carbon innovation; and (c) a negative linear relationship between low-carbon innovation and corporate carbon emission intensity.

Organizations adopt different strategies to foster creative and innovative behavior for competitive advantage and survival (Gumusluoglu et al., 2017). Low-carbon innovation has become one of the effective means. Innovative behavior is generated based on the differences between members. Social identity theory suggests that team identity allows individuals to derive self-definition from the team but it does not necessarily encourage them to engage in innovative behavior (Janssen and Huang, 2008). At low-to-moderate stages of DTG, team members put performance first, and they are also less likely to engage in slower and risky innovation behaviors, even if they argue that innovation is important for the achievement of performance. In this context, we argue that low-to-moderate DTG may or not be inclined to engage in innovation activities.

With the increase in DTG, team members have more resources for environmental awareness and environmental innovation and a high team identity sense might be expected to exert a positive influence on team's innovation behavior (Mascitelli, 2000). Meanwhile, team members no longer focus on obtaining team identity, but on how to have a better performance presentation and achieve further team development. Thus, we argue with a longer DTG is inclined to engage in innovation activities, which is supported by resource dependence theory.

Regarding the linear relationship between low-carbon innovation and corporate carbon emission intensity, we argue that the more low-carbon innovation, the more corporations can decrease carbon emission intensity. Innovation is the main driver for low-carbon development (Zhang et al., 2020). Although investment in GHG reduction innovation requires scarce resources without generating immediate financial gain, low-carbon innovation is viewed as the key factor affecting corporate carbon emission reduction (Mensah et al., 2018). Innovation activities of corporations can achieve carbon emission reduction or energy efficiency technology improvement through the development of relevant technologies for carbon emission reduction (Mo, 2022). Therefore, we propose the following hypothesis. For the details. Please see fig. 4.

Hypothesis 4: Low-carbon innovation is a channel for DTG to decrease corporate carbon emission intensity.

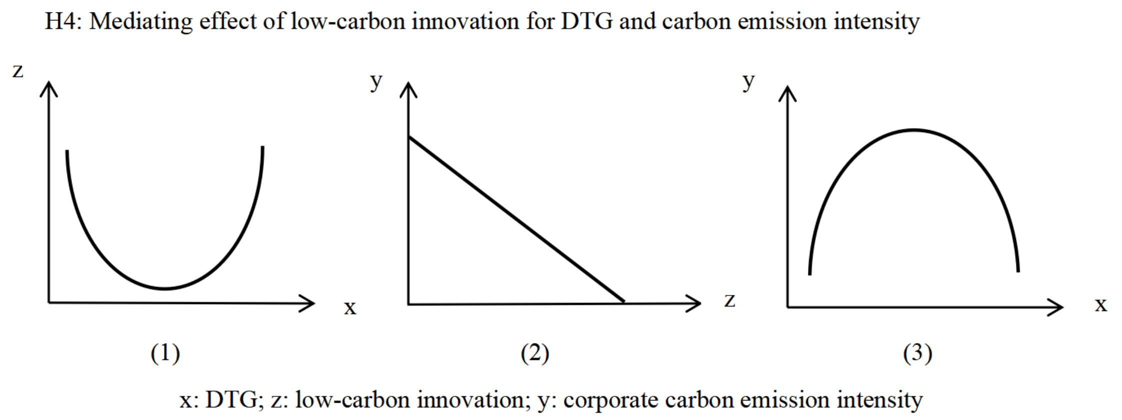

Fig. 4. Transmission channel of the mediator.

Data Collecting and Research method

Data Collecting

We build an unbalanced panel data of 608 U.S. listed corporations during 2009 to 2018, which reported by the CDP, Compustat database and the BoardEx database. The earliest data that CDP has available is 2009. The CDP report is a shared database used to research for recent corporate carbon emissions (Dahlmann et al., 2019). The CDP database covers information on governance, risks and opportunities, business strategy, targets and performance, emissions, carbon pricing, and other land management impacts and sign-off (CDP, 2020). Over 95% of the world's largest 500 corporations now voluntarily provide information to the CDP. We gather data of independent and dependent variables, mediator variable and carbon emission-related characteristics from the standardized CDP questionnaire. Compustat database provides detailed quarterly and annual financial statements and historical data on financial indicators for more than 24,000 publicly traded corporations in the United States and Canada. The database contains nearly 20 years of financial data for North America. We gather data related to corporate characteristics and corporate financial information from the Compustat database. The BoardEx database is commonly used in empirical research regarding board characteristics and diversity (Kang et al., 2020). We use the BoardEx database from 2009 to 2018 to construct team size (*TSize*) and gender diversity (*GenderD*) indices, and gather team level characteristics.

According to each company name, we determine its ticker symbol in the American Stock Exchange, and according to the ticker symbol, we match the data with the BoardEx database, CDP report, and the Compustat database to form our sample. Observations are eliminated from our sample according to the following criteria: missing carbon emissions data, incomplete or missing corporate governance data, and missing financial data from Compustat. Finally, reserve 3460 observations. To mitigate the effect of outliers in our subsequent tests, we also winsorize all corporations-year continuous variables at the levels of 1% and 99%. Table 1 presents the descriptive statistics for our sample.

Variable Measurement

Firstly, our dependent variable is corporate carbon emission intensity. To overcome the differences across corporations, we introduce relative quantities to represent the changes in emissions intensity, metric ton carbon emission per revenue (revenue intensity) as a carbon intensity measure. $LnRin_{i,t}$ is the natural logarithm of revenue intensity. According to the questions 'What were your organisation's gross global Scope 1 emissions in metric tons CO_2e?' and 'Describe your organisation's approach to reporting Scope 2 emissions', we sum corporations' direct/scope 1 and indirect/scope 2 carbon emissions to capture a corporation's total carbon emissions in each year[1], which is widely use in carbon performance researches (Bui et al., 2020; Haque and Ntim, 2020; Dahlmann et al., 2019). We take a corporation's total operating income each year as stated in the Compustat database as our denominator. In the robustness tests, we use the absolute carbon emissions (*Total*/*Scope 1*/*Scope 2*) and the relative carbon intensity of scope 1 and scope 2 (*LnRrin*/*LnRinn*/*LnEein*/*LnEinn*) as the explained variable.

Our core independent variable is duration of team governance (*DTG)*. We obtain the role of managers occupying the highest level of direct responsibility for climate change within the organization in the CDP reports on the following two questions: 'Where is the highest level of direct responsibility for climate change within your organization?' and 'Identify the position(s) of the individual(s) on the board with responsibility for climate-related issues'. In manually, we scrutinized the descriptions of managers' role, furthermore we screened the corporations allocating the responsibility on boards and committees. What we have manually scrutinized data are dummy variables, which is "0" if the firm does not adopt team governance, "1" if the firm adopt team governance. But only depending on dummy variables couldn't study the

1 Scope 1 emissions are referred to as 'emissions from sources that are owned or controlled by the organization', such as: stationary combustion, from the combustion of fossil fuels (e.g., natural gas, fuel oil, propane, etc.), for comfort heating or other industrial applications; mobile combustion, from the combustion of fossil fuels (e.g., gasoline, diesel), used in the operation of vehicles or other forms of transportation; process emissions released during the manufacturing process in specific industry sectors (e.g., cement, iron and steel, ammonia); and fugitive emissions, which are unintentional releases of GHG from sources including refrigerant systems and natural gas distribution. Scope 2 emissions account for 'emissions from the consumption of purchased electricity, steam, or other sources of energy (e.g., chilled water) generated upstream of the organization'. Scope 3 emissions are defined as indirect 'emissions that are a consequence of the operations of an organization but are not directly owned or controlled by the organization'. Scope 3 emissions include several different sources of GHG, including employee commuting, business travel, third-party distribution and logistics, production of purchased goods, emissions from the use of sold products, and several more.

change of effectiveness in the process of team development. According to the group development theory, we use DTG - the length of occupying the highest level of direct responsibility for climate change within an organization as our core independent variable. Specifically, as time changes, we proxy the dummy variable "1" appears for the first time, we consider *DTG* to be Year 1. When the dummy variable "1" appears for the second time, we consider *DTG* to be Years 2 , and so on. If a firm does not adopt team governance after several years, it is defined as "0" for the year in which it stops using it and for the subsequent years in which it is not used, and starts to accumulate years of using again when it starts using it again. Furthermore, we add the quadratic term variable DTG^2 to examine the nonlinear relationship in the model.

We use team size (*TSize*) and gender diversity (*GenderD*) as moderating variables. Size is the basis of team governance, and team size greatly affects the effectiveness of team governance. Thus, the total number of team members is selected as a proxy variable of size. Further, we employ a series of binary variables (one member, two members, three members, and more) to test the moderating effects of a 'critical mass' of team members number on corporate carbon emission intensity (Ben-Amar et al., 2017). We use gender diversity as the variable. Gender diversity is constructed using Blau's index of heterogeneity, calculated as $H = 1 - \sum P_i^2$, where P is the proportion of individuals (directors) in a category, and i is the number of categories (Zorn et al., 2020). In this study, gender diversity is the index of heterogeneity for gender with two categories: men and women. Based on our data, we find that there are always fewer women on the team than men. We therefore measure gender diversity as a percentage of women in the total team. Further, we also employ a series of binary variables (one woman, two women, three women, and more) to test the moderating effects of a 'critical mass' of women members number on DTG on corporate carbon emission intensity.

We use low-carbon innovation (*Lowinn*) as the mediating variable. We measure corporate low-carbon innovation from the low-carbon products and services provided in the CDP report. CDP report provides this information from 2015. Here we choose corporate green production revenue from 2015-2019 to measure corporate green innovation. We obtain revenue from corporations-related low-carbon products and services from item: "C4.5 Provide details of your products and/or services that you classify as low-carbon products or that enable a third party to avoid GHG emissions. - % revenue from low carbon product(s) in the reporting year" to measure corporate green innovation.

We include several control variables used in prior studies (Chen, 2020) including corporate and board-specific characteristics and corporate carbon emission intensity characteristics due to the natural of the study. Firstly, we control a series of corporate-specific characteristics in our models. Firm size (*Fsize*) is measured by the natural logarithm of the number of employees at the end of the fiscal year. Firm leverage (*Leverage*) is defined as long-term debt plus current liabilities divided by total assets. Return of ratio (*ROA*) is operating income before depreciation divided by total assets. Advertise is the ratio of advertising expenses divided by total assets. R&D Intensity (*R&D*) is the annual dollars spent on R&D scaled by total assets. Market value of equity (*MB*) is the ratio of market value of assets over book value of assets. Asset intensity (*Asse*t) is the ratio of total assets divided by equivalent employees. Increased investment (*IVCH*) is the annual dollars spent on increased investment. Secondly, we control a series of corporate carbon emission intensity characteristics in our model. Corporate carbon emission trading schemes (*Scheme*) is an indicator that equals '1' if corporations participate in any emission trading schemes. Corporate carbon emission target (*Target*) is an indicator that equals '1' if corporations have an emissions reduction or renewable energy consumption or production target that was active (ongoing or reached completion) in the reporting year. Corporate Voluntary information release (*Voluntary*) is an indicator that equals '1' if corporations publish information about responding to climate change and GHG emissions performance for this reporting year in places other than in your CDP response, such as CSR reports. Incentive target (*Incentive*) is an indicator that equals '1' if corporations provide incentives for management of climate change issues, including the attainment of targets. Corporate carbon emission strategy (*Strategy*) is an indicator that equals '1' if corporations use methods to drive investment in emissions reduction activities. Finally, we control for board-specific characteristics in our model. Independent directors (*Director*) is a total number of independent directors. Executive Directors (*Exdirector*) is a total number of executive directors.

Table 1 Measurement of variables.

Variable name	Definition	Sign	Date source
Dependent variables			
Carbon emissions per revenues (*Rin*)	The natural logarithm of scope 1 and 2 carbon emissions/total operating revenue.		CDP
Carbon emissions per full time equivalent employees (*Ein*)	The natural logarithm of scope 1 and 2 carbon emissions/equivalent employees		CDP
Main variables			
Duration of team governance (*DTG*)	The length of teams that occupies the highest level of direct responsibility for climate change within organization.	+/ GDT	CDP
Duration of team governance quadratic (*DTG* ^{2})	The square of *DTG*	-/ GDT	CDP
Mediator			
Low-carbon innovation (*Lowinno*)	The share of revenue from green development in total revenue	+/SIT&RDT	CDP
Moderators			
Team size (*TSize*)	Total number of directors	+/- /SIT&RDT	BoardEx
Gender diversity (*GenderD*)	Blau (1977) index of heterogeneity. $H = 1 - \sum P_i^2$, where *i* number of categories (2 for gender diversity) and *p* is the proportion of group members (fraction of women and men directors) in each category.	+/- /SIT&RDT	BoardEx
Control variables-firm level			
Firm size (*Fsize*)	The natural logarithm of the number of employees at the end of the fiscal year.	-	Compustat
Firm leverage (*Leverage*)	The natural logarithm of long-term debt plus current liabilities deflated by total assets.	-	Compustat
R&D Intensity (*R&D*)	The natural logarithm of the annual dollars spent on R&D scaled by total assets.	+	Compustat
Return of assets (*ROA*)	The natural logarithm of operating income before depreciation is divided by total assets.	+	Compustat
Market value of equity (*MB*)	The natural logarithm of the ratio of the market value of equity is measured as the price times shares outstanding over the book value of the equity.	-	Compustat
Asset intensity (*Asset*)	The natural logarithm of total assets divided by all employees.	+	Compustat
Increased investment (*IVCH*)	The natural logarithm of increased investment	+	Compustat
Control variables-Carbon emission level			
Corporate carbon emission trading schemes (*Scheme*)	Dummy variable with the value of '1' if corporations participate in any emission trading schemes.	+	CDP
Corporate carbon emission target (*Target*)	Dummy variable with the value of '1' if corporations have an emissions reduction or renewable energy consumption or production target that was active (ongoing or reached completion) in the reporting year.	+	CDP

Corporate Voluntary information release (*Voluntary*)	Dummy variable with the value of '1' if corporations publish information about responding to climate change and GHG emissions performance for this reporting year in places other than in your CDP response	+	CDP
Incentive target (*Incentive*)	Dummy variable with the value of '1' if corporations provide incentives for the management of climate change issues, including the attainment of targets.	+	CDP
Corporate carbon emission strategy (*Strategy*)	Dummy variable with the value of '1' if corporations use methods to drive investment in emissions reduction activities.	+	CDP
Control variables-team level			
Independent directors (*Director*)	Total number of independent directors	+/-	BoardEx
Executive Directors (*Exdirector*)	Total number of Executive Directors	+	BoardEx

Notes: CDP (Carbon Disclosure Project) is a United Kingdom-based not-for-profit charity organization that collects and disseminates greenhouse gas-related information voluntarily disclosed by firms. Compustat is the historical data of detailed quarterly and annual financial statements and financial indicators of listed corporations in the United States and Canada. BoardEx is North American executive and company information database.

Table 2 presents the correlations among the independent, dependent, and control variables. The multicollinearity test is also reported here. The highest variance inflation factor (VIF) is 2.66, well below the threshold of 10 for the risk of multicollinearity, which indicates that there is no serious multicollinearity among variables. Detailed information of sample firms is supplemented in the appendix. Appendix 1 provides the number of corporations in various industries of the sample and the average duration of firms adopting team governance and observations in various industries. Appendix 2 provides we provide the average revenue intensity, average employee intensity, average total emissions, average Scope 1 emissions and average Scope 2 emissions of establishment of firms in various industries of the sample. Appendix 3 provides the average Scope 1 revenue intensity, average Scope 2 revenue intensity, average Scope 1 employee intensity and average Scope 2 employee intensity of establishment of corporations in various industries of the sample.

Regression models

The purpose of this study is to examine the impact of DTG on corporate carbon emission intensity. To determine whether fixed effect models are selected or not, we first use the Hausman tests. The Hausman tests results show a p-value of 0.0004, which is less than 1% (0.01). The null hypothesis that random effect is the appropriate model for our study is rejected. Thus, we adopt fixed effect (FE) approaches in the unbalanced panel regression estimation.

Besides these, we further test the moderating effects of team size and gender diversity on team effectiveness.

Our multiple regression equation is as follows:

$$LnRin_{i,t} = \beta_0 + \beta_1 DTG_{i,t} + \beta_4 DTG_{i,t}^2 + \beta_2 TSize_{i,t} + \beta_3 GenderD_{i,t} + \beta_5 DTG_{i,t} \times TSize_{i,t} + \beta_6 DTG_{i,t}^2 \times TSize_{i,t} + \beta_7 DTG_{i,t} \times GenderD_{i,t} + \beta_8 DTG_{i,t}^2 \times GenderD_{i,t} + \beta_9 Controls_{i,t} + \alpha_i + \delta_t + \varepsilon_{i,t} \quad (1)$$

where $LnRin_{i,t}$ is the natural logarithm of revenue carbon intensity for the corporation i in year t; $DTG_{i,t}$ is duration of team governance; $DTG_{i,t}^2$ is the square of DTG; $TSize_{i.t}$ is a moderating variable, which refers to team size; $GenderD_{i.t}$ is a moderating variable, which refers to gender diversity; $Controls_{i,t}$ is control variables, which refers to the set of our control factors relating to firm-specific, carbon emission-specific and team-specific factors; α_i is the firm fixed effect; δ_t is the year fixed effect; $\varepsilon_{i,t}$ is the error term.

Table 2

Descriptive statistics and correlation matrix.

	Mean	SD	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
(1)*Rin*	8.1228	3.9398	1																				
(2)*Ein*	8.9326	3.2668	0.942***	1																			
(3) *DTG*	2.5155	3.0121	0.082***	-0.0250	1																		
(4) DTG^2	15.3981	25.2093	0.058***	-0.0280	0.951***	1																	
(5) *TSize*	22.1253	9.3276	-0.144***	-0.193***	0.194***	0.171***	1																
(6) *GenderD*	0.2301	0.1112	-0.0220	-0.060***	0.181***	0.166***	0.397***	1															
(7) *Budget*	0.2214	0.4153	0.094***	0.070***	0.029*	0.0160	0.071***	0.00800	1														
(8) *Fsize*	3.3924	1.4090	0.144***	0.107***	0.126***	0.110***	0.122***	-0.0250	0.127***	1													
(9) *Leverage*	-1.4431	0.7731	0.200***	0.062***	0.216***	0.190***	0.081***	0.100***	0.151***	0.210***	1												
(10) *R&D*	-3.7820	1.1560	0.190***	0.096***	0.199***	0.190***	0.090***	0.093***	0.154***	0.212***	0.396***	1											
(11) *ROA*	-2.1709	0.6423	0.103***	0.0160	0.0150	-0.0230	0.086***	0.129***	0.079***	0.097***	0.177***	0.166***	1										
(12) *MB*	0.4805	0.4387	0.174***	0.093***	0.216***	0.190***	0.077***	0.060***	0.104***	0.167***	0.286***	0.375***	0.074***	1									
(13) *Asset*	6.5930	1.3900	0.255***	0.169***	0.089***	0.084***	0.227***	0.135***	0.121***	0.188***	0.188***	0.142***	0.079***	0.094***	1								
(14) *IVCH*	6.4481	2.9784	0.221***	0.265***	0.056***	0.077***	-0.00400	0.062***	0.0140	0.076***	0.121***	0.105***	-0.0290	0.119***	0	1							
(15) *Scheme*	0.3055	0.4607	0.358***	0.405***	0.084***	-0.072**	0.095***	0.083***	0.050*	0.153***	-0.0480	0.081***	0.00900	0.106***	0.085***	0.104***	1						
(16) *Target*	0.7589	0.4278	0.042**	0.066***	0.216***	-0.00400	0.163***	0.063***	0.0190	-0.0100	0.046**	0.038*	0.00800	0.107***	0.100***	0.140***	0.168***	1					
(17) *Incentive*	0.7620	0.4259	0.103***	0.126***	0.096***	0.105***	0.091***	0.083***	-0.0290	-0.0330	0.083***	0.066***	0.00800	0.116***	0.045**	0.133***	0.307***	0.642***	1				
(18) *Voluntary*	0.6659	0.4717	0.077***	0.109***	0.102***	0.097***	0.122***	-0.062**	0.038*	0.111***	-0.052**	0.055***	0.041*	-0.0260	0.486***	-0.052**	0.086***	0.539***	0.385***	1			
(19) *Strategy*	0.8396	0.3670	0.0380	0.0360	0.126***	0.124***	0.263***	0.0340	0.113***	0.182***	0.136***	0.125***	0.147***	0.0120	0.339***	0.167***	0.309***	0.338***	0.146***	0.439***	1		
(20) *Director*	8.8343	4.7490	0.066***	0.110***	0.046***	0.062***	0.220***	0.097***	0.058***	0.090***	0.00700	-0.037**	0.033*	0.056***	0.147***	0.088***	-0.0480	0.108***	0.069***	-0.0190	0.106***	1	
(21) *Exdirector*	14.1923	7.7001	0.065***	0.115***	0.116***	0.115***	0.223***	0.076***	0.069***	0.127***	0.052***	0.088***	0.110***	0.035**	0.115***	0.00900	-0.056*	0.156***	0.064***	0.159***	0.280***	-0.00600	1

Notes:(*), (**) and (***) indicates that the coefficients are significant or the relevant null is rejected at the 10, 5 and 1 percent level, respectively. See Table 1 for the definition of the variables.

To reveal the channels through which DTG affects corporate carbon emission intensity, we introduce a mediating variable, low-carbon innovation, to explore whether DTG affects corporate carbon emission intensity directly or indirectly.

$$Lowinno_{i,t} = \beta_0 + \beta_1 DTG_{i,t} + \beta_2 DTG^2_{i,t} + \lambda Controls_{i,t} + \alpha_i + \delta_t + \varepsilon_{i,t} \tag{2}$$

$$LnRin_{i,t} = \beta_0 + \beta_1 DTG_{i,t} + \beta_2 DTG^2_{i,t} + \varphi Lowinno_{i,t} + \xi Controls_{i,t} + \alpha_i + \delta_t + \varepsilon_{i,t} \tag{3}$$

where $Lowinno_{i.t}$ is a mediating variable, which refers to low-carbon innovation.

The steps of the mediation effect test are reported as:

Step 1: We check the coefficients β_1 and β_2 in Eq. (2). If they are significant, the coefficient β_1 is positive (negative) and the coefficient β_2 is negative (positive), there is a mediation effect, and go to step 2.

Step 2: We check the coefficient β_1 and β_2 in Eq. (2) and the coefficient φ in Eq. (3). If they are all significant, and go to step 3. If at least one is not significant, stop the analysis.

Step 3: We check the coefficients β_1 and β_2 in Eq. (3). If it is not significant, it indicates that the model has full mediation effect. If it is significant, go to step 4.

Step 4: We check the sign of φ. If the coefficient β_1 and φ is significant and have the same sign, the model has partial mediation effect. If the coefficient β_1 and φ opposite in sign, stop the analysis.

Analytical approach

Firstly, we conduct the Hausman test to determine the regression model. According to the results, we choose fixed effect models to measure the relationship between DTG and corporate carbon emission intensity, with the advantages of fixing the effects of corporations and year.

Secondly, we use DTG for regression analysis and explore the nonlinear relationships. We include DTG^2 in our model and find that its coefficient is negative and is significant, indicating the relationship between DTG and corporate carbon emission intensity is inverted U-shaped. To address endogeneity, we employ the instrumental variable approach and Heckman's Two-step Procedure to alleviate the endogeneity.

Thirdly, to explore the proposed underlying mechanism of DTG and corporate carbon emission intensity, we explore the effects of the two moderating variables (team size and gender diversity) on the relationship obtained with the baseline model. Further, we examine the optimal team size and gender diversity.

Finally, we select low-carbon innovation as the mediating variable to find a potential channel between DTG and corporate carbon emission intensity.

Regression results and discussions

Baseline regression results

Table 3 reports the estimation results of DTG on corporate carbon emission intensity. Baseline regression results are present in panel A of Table 3. We add the square of DTG to examine the nonlinear relationship between DTG and corporate carbon emission intensity. In columns (1) and (2), we find the coefficients of *DTG* is significantly positive and DTG^2 is significantly negative, which indicates DTG have an inverted U-shaped relationship with corporate carbon emission intensity. Hypothesis 1 is confirmed. The turning point of the inverted U-shaped curve is obtained at 6.52 ($2 \times \beta DTG^2 \times DTG_{\max} + \beta DTG = 0$, that is, $DTG_{\max} = -\beta DTG/2\beta DTG^2$, where $DTG_{\max}$ is the value of the turning point). Therefore, DTG decreases corporate carbon emission intensity if DTG exceeds 6.52 years. Otherwise, DTG results in a higher corporate carbon emission intensity, which means that a shorter DTG is not conducive to decreasing corporate carbon emission intensity. With the extension of DTG, teams are beginning to positively decrease corporate carbon emission intensity.

Further, we implement a two-stage least squares (2SLS) instrumental variables approach to alleviate endogeneity concerns (Li et al., 2021), and use the Heckman two-step method to solve the problem of potential self-selection bias (Wolfolds and Siegel, 2019). We use nationality mix (*National*) as a DTG instrumental variable, which is measured by the proportion of team members from different countries at the annual report date selected. As shown in panels B and C of Table 3.

Table 3 Addressing the endogeneity.

Variable	panel A: Baseline regression results		panel B: IV method			panel C: Heckman's two-step procedure
			DTG	*LnRin*	*LnRin*	
	LnRin		First stage	Second stage	Second stage	*LnRin*
DTG(*IV*)	0.3667*** (0.0814)	0.3678** (0.1537)		-0.664** (0.30)	1.154** (0.47)	0.2427*** (3.91)
DTG^2 (IV^2)	-0.0246*** (0.0060)	-0.0282** (0.0108)			-0.073** (0.03)	-0.0195** (-2.57)
National			4.851*** (1.386)			
Scheme						0.7760*** (3.44)
Target						1.8423*** (9.97)
Incentive						0.5051** (2.56)
Voluntary						0.6731*** (3.84)
Strategy						0.2256 (1.12)
Control variables	NO	YES	YES	YES	YES	YES
Firm fixed effect	YES	YES	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES	YES	YES
N	3460	3460	3460	3460	3460	3460
R^2	0.0244	0.1789	-0.628		0.139	
lambda						-0.359
Rho						-0.314
LM statistic				7.618 [0.0058]		
Cragg-Donald Wald F				9.717		
Kleibergen-Paap rk Wald F statistic				12.428		

Notes: The dependent variable in the regression is *LnRin. LnRin* is carbon emissions per revenues. All the estimations have controlled for firm fixed effects and year fixed effects. The standard errors robust to heteroscedasticity, clustered by firm level, are reported in the parentheses. In IV method test, we use two-stage least squares (2SLS) to address endogeneity. In first-stage regression, we use endogenous variables to perform OLS regression on instrument variable (*National*), so as to separate the exogenous part of the endogenous variables. In the second stage of regression, we substitute the fitted values obtained from the first stage of regression into the OLS model and replace the endogenous variables in the original model with them to obtain a consistent estimate. The p-value of underidentification test (Kleibergen-Paap rk LM statistic) is 0.0058, which strongly rejects the unidentified null hypothesis. The result is reported in square brackets. The Cragg-Donald Wald F statistic is 9.717, and the Kleibergen-Paap rk Wald F statistic is 12.428. In Heckman's two-step procedure test, firstly, we perform probit regression by selecting scheme, target, incentive, voluntary, and strategy as the independent variables, and taking corporate carbon emission intensity as the dependent variable. Secondly, the estimated inverse Mills ratio is taken as a control variable in the regression model of DTG affecting corporate carbon emission intensity to control for selection bias. The results show that the coefficient of lambda is not significant, indicating that there is no sample self-selection bias All reject the weak instrument hypothesis. (*), (**) and (***) indicate that the coefficients are significant or the relevant null is rejected at the 10, 5, and 1 percent level, respectively. See Table 1 for the definition of variables.

Robustness tests

We perform some robustness tests to make our regression results more reliable. Firstly, when the true relationship between the independent and the dependent variables is concave but monotone over the *DTG* values, a quadratic specification may then erroneously identify an extreme point and hence a U-shape, thus, forming a pseudo inverted U-shape. In this monotonically rising half of the data, the coefficient of a square term (DTG^2) is significant, but it does not prove that the second half of the data will go down. Therefore, to avoid such pseudo-regression, we use the U test for verification (Ener, 2019; Lind and Mehlum, 2007). As shown in Panel A of Table 4.

Secondly, when testing U-shaped or inverted U-shaped relationships, a cubic term is added into ruling out the possibility of an S-shaped relationship (Haans et al., 2016). If adding the cubic term does not improve the model fit, then there is strong support for a quadratic relationship. Besides, consider that fixed effect models automatically drop data that does not vary over time to causes potential omitted variables issues, we add random effect models to rerun our regressions (Al-Shammari et al., 2021). As shown in Panel B of Table 4.

Table 4 U-test and test excluding the cubic term tests regression results.

Panel A: U-test regression result		
Utest	Lower bound	Upper bound
Interval	0	10
Slope	0.3678	-0.1970
t-value	1.94	
P>|t|	0 .0277	

Panel B: Cubic term regression result			
	LnRin		
Variable	Fixed effect model	Random effect model	Random effect model
DTG	0.7966*** (0.2079)	0.3267*** (0.1125)	0.5774*** (0.1980)
DTG^2	-0.1058** (0.0489)	-0.0242*** (0.0093)	-0.1036*** (0.0505)
DTG^3	0.0044 (0.0035)	--	0.0058 (0.0038)
Control variables	YES	YES	YES
Firm fixed effect	YES	YES	YES
Year fixed effect	YES	YES	YES
N	3460	3460	3460
R^2	0.4152	0.1596	0.1826

Notes: The dependent variable in the regression is *LnRin*. *LnRin* is carbon emissions per revenues. DTG^3 is the cubic term of *DTG*. In panel A, the extreme point lies at 6.5, and the reject the null hypothesis is rejected at the level of 5% within the range of *DTG* (P>|t|=0.0277). The slope in the result has a negative sign in the interval, which as an inverted U-shaped relationship is identified. The standard errors robust to heteroscedasticity, clustered by firm level, are reported in the parentheses. (*), (**) and (***) indicate that the coefficients are significant or the relevant null is rejected at the 10, 5, and 1 percent level, respectively. See Table 1 for the definition of variables.

Thirdly, we repeat our analysis using employee intensity (*LnEin*) as an alternative carbon intensity measure variable. The variable LnEin is the natural logarithm of metric ton carbon emission per full time equivalent employee. As shown in Panel A of Table 5.

Fourthly, we use absolute emissions quantities instead of relative emissions quantities to verify our result. Dahlmann et al. (2017) argue that intensity targets are more symbolic and relatively weaker compared to absolute targets for measuring actual emissions. Specifically, we use relative emissions quantities and absolute emissions of Scope 1 and Scope 2 individually as alternative measures. The absolute qualities include the natural logarithm of the sum of Scope 1 and 2 emissions (*LnTotal*), the natural logarithm of Scope 1 (*LnScope1*) and the natural logarithm of Scope 2 (*LnScope2*). The relative quantities include scope1 carbon emissions per revenues (*LnRrin*), scope1 carbon emissions per full time equivalent employees (*LnEein*), scope 2 carbon emissions per revenues (*LnRinn*), the reciprocal of scope 2 carbon emissions per full time equivalent employees (*LnEinn*). The regression results are reported in Panel A of Table 5.

Fifthly, to examine a sufficient condition of a quadratic relationship form, we test if the first part of the curve has a positive slope and if the second part has a negative one (Lind and Medhlum, 2010). We split main sample in terms of the year of the curve inflection point 6.52 is the inflection point year. For the operability of sample, we select 7 years as the distinguished year of the sample. Ultimately, our main sample is divided into two groups of 2009-2016 and 2017-2018. The existence of a quadratic relationship is shown in Panel C of Table 5.

Finally, for our study, the CDP data obtained started in 2009. When individuals occupied the highest level of direct responsibility for climate change within an organization in 2009 and responsibility shifted to a team in 2010, we are able to determine DTG. However, when team occupied the highest level of direct responsibility for climate change within the organization in 2009, we can not sure if that appointment was in 2009 or even a few years earlier. As a result, for corporations in 2009, DTG is uncertain. Here, we delete all the corporations in 2009. We take the value of 1 for corporations, when a team occupied the highest level of direct responsibility for climate change within the organization in 2010. As shown in panel D of Table

5.

Table 5 Partial sample tests.

Panel A: Alternative measures of corporate carbon emission intensity results

Variable	*LnEin*	
	(1)	(2)
DTG	0.1124**	0.2087**
	(0.0556)	(0.0816)
DTG²	-0.0088**	-0.0144**
	(0.0037)	(0.0058)
Control variables	NO	YES
Firm fixed effect	YES	YES
Year fixed effect	YES	YES
N	3320	3320
R^2	0.5728	0.6448

Panel B: The composition of corporate carbon emission intensity regression results

Variable	*LnTotal*	*LnScope1*	*LnScope2*	*LnRrin*	*LnRinn*	*LnEein*	*LnEinn*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DTG	0.3633***	0.3536***	0.1867**	0.5505***	0.3444**	0.3521***	0.1867**
	(0.1135)	(0.1233)	(0.0824)	(0.1492)	(0.1591)	(0.1231)	(0.0824)
DTG²	-0.0271***	-0.0296***	-0.0134**	-0.0442***	-0.0271**	-0.0294***	-0.0134**
	(0.0088)	(0.0099)	(0.0059)	(0.0136)	(0.0109)	(0.0099)	(0.0059)
Control variables	YES	YES	YES	YES	YES	YES	YES
Firm fixed effect	YES	YES	YES	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES	YES	YES	YES
N	3246	3246	3246	3246	3246	3246	3246
R^2	0.4319	0.3053	0.2268	0.3499	0.1794	0.6133	0.6826

Panel C: Quadratic relationship form test

Variable	*LnRin*	
	Lower bound	Upper bound
DTG	1.3515***	-0.4270**
	(0.4111)	(0.2061)
Control variables	YES	YES
Firm fixed effect	YES	YES
Year fixed effect	YES	YES
N	2307	1156
R^2	0.8798	0.2175

Panel D: Eliminate 2009 corporate regression results

Variable	*LnRin*	
	(1)	(2)
DTG	0.3988**	0.8701**
	(0.1923)	(0.3108)
DTG²	-0.0332**	-0.0899**
	(0.0128)	(0.0352)
Control variables	NO	YES
Firm fixed effect	YES	YES
Year fixed effect	YES	YES
N	1178	1178
R^2	0.0309	0.6347

Notes: The dependent variable in the regression is either *LnRin* or *LnEin*. *LnRin* is carbon emissions per revenues. *LnEin* is carbon emissions per full time equivalent employees. The quadratic relationship form tests show that both slopes are significant and the left-hand side is positive and the right-hand side is negative, which provides very strong support for the existence of a quadratic relationship. All the estimations have controlled for firm fixed effects and year fixed effects. The standard errors robust to heteroscedasticity, clustered by firm level, are reported in the parentheses. (*), (**) and (***) indicate that the coefficients are significant or the relevant null is rejected at the 10, 5, and 1 percent level, respectively. See Table 1 for the definition of variables.

Moderating effects

We examine the moderating effect of team size and gender diversity. Not only examine how team size and gender diversity affect corporate carbon emission intensity, but also explore the optimal team size and gender diversity for DTG. As shown in Table 6.

In Column (1), the estimated coefficient of *TSize* is -0.0124 and is insignificant, which means that size alone does not affect corporate carbon emission intensity, and its effectiveness must be combined with teams to play a role. In columns (2) and (3), we gradually add the interaction terms $TSize \times DTG$ and $TSize \times DTG^2$. We find that *TSize* flattens the negative linear function of the inverted U-shaped curve ($TSize \times DTG$=-0.0703) and the positive linear function of the inverted U-shaped curve ($TSize \times DTG^2$=0.0076). Corporate carbon emission intensity reaches its maximum point of 4.56 when $\beta DTG + 2 \times \beta DTG^2 \times DTG_{\max} + \beta DTG \times TSize \times TSize = 0$, that is, $DTG_{\max} = -\beta DTG - \beta DTG \times TSize \times TSize / 2\beta DTG^2$, which means that *TSize* moderates the relationship of DTG with corporate carbon emission intensity by affecting the negative mechanism and the positive impacts, shifting the turning point of the curve to the left. This finding shows that size weakens the negative and positive mechanism of DTG to corporate carbon emission intensity, which supports hypothesis 2.

In columns (4) and (5), we gradually add the interaction terms $GenderD \times DTG$ and $GenderD \times DTG^2$. We find that *GenderD* flattens the negative linear function of the inverted U-shaped curve ($GenderD \times DTG$=-1.2512) and the positive linear function of the inverted U-shaped curve ($GenderD \times DTG^2$=0.1692). Corporate carbon emission intensity reaches its maximum point of 3.56 when $\beta DTG + 2 \times \beta DTG^2 \times DTG_{\max} + \beta DTG \times GenderD \times GenderD = 0$, that is, $DTG_{\max} = -\beta DTG - \beta DTG \times GenderD \times GenderD / 2\beta DTG^2$, which means that *GenderD* moderates the relationship between DTG and corporate carbon emission intensity by affecting the negative mechanism and the positive mechanism, shifting the turning point of the curve to the left. Thus, gender diversity weakens the negative and positive impacts of DTG on corporate carbon emission intensity, which supports hypothesis 3. Columns (6) includes two moderating variables *TSize* and *GenderD* in the same models to compare the significance levels of the two corresponding coefficients. The results are consistent. Corporate carbon emission intensity reaches its maximum point of 4.52, which indicates team size and gender diversity advance the effective of DTG.

Further, we predict the optimal team sizes. We run regressions with a series of binary variables and control variables. The first binary variable takes the value of '1' if there is at least one member on the team and '0' otherwise. The second binary variable takes the value of '1' when there are at least two members on the team and '0' otherwise. The third binary variable takes the value of '1' when there are at least three members on team and '0' otherwise, and so on, all the way to the thirty-first binary variable which takes the value of '1' when there are at least thirty-one members on the team and '0' otherwise. We define these binary variables as *Tamount*. The results are presented in Appendix 1. We find that 11 team members are the threshold upper limit of the number of team members. Therefore, size has the optimal moderating effect on DTG and corporate carbon emission intensity with 8-11 members. Similarly, we also predict the critical mass of women members. For women members, we use the same mutator. We define these binary variables as *Gamount*. The results are presented in Appendix 2. We find that in the context of climate change governance, a team of three-to-four women members is the best at making effective decisions that decrease corporate carbon emission intensity.

Table 6 Moderating effects of team size.

Variable	*LnRin*					
	(1)	(2)	(3)	(4)	(5)	(6)
DTG	0.5583***	0.1770	2.1263***	0.1467	0.3862**	2.7669***
	(0.1510)	(0.1283)	(0.4317)	(0.1027)	(0.1617)	(0.6510)
TSize	-0.0124	-0.0167	0.0057	-0.0583*	0.0045	0.0300
	(0.0133)	(0.0321)	(0.0198)	(0.0343)	(0.0078)	(0.0222)
GenderD	-0.8156	6.7389**	6.1529***	11.0037***	1.2673	3.9353**
	(1.0217)	(3.0521)	(1.9246)	(3.8875)	(1.2335)	(1.7872)
DTG^2	-0.0414***		-0.2332***		-0.0543***	-0.3058***
	(0.0127)		(0.0456)		(0.0198)	(0.0736)
TSize×DTG		-0.0064**	-0.0703***			-0.0931***
		(0.0030)	(0.0131)			(0.0223)

TSize×DTG²			0.0076*** (0.0014)			0.0094*** (0.0023)
GenderD×DTG				-1.1195** (0.4244)	-1.2512* (0.7022)	-1.1226 (0.6710)
GenderD×DTG²					0.1692* (0.0885)	0.1299* (0.0772)
Control variables	YES	YES	YES	YES	YES	YES
Firm fixed effect	YES	YES	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES	YES	YES
N	3460	3460	3460	3460	3460	3460
R^2	0.4120	0.5960	0.8176	0.6235	0.2666	0.780

Notes: The dependent variable in the regression is *LnRin. LnRin* is carbon emissions per revenues. All the estimations have controlled for firm fixed effects and year fixed effects. The standard errors robust to heteroscedasticity, clustered by firm level, are reported in the parentheses. (*), (**) and (***) indicate that the coefficients are significant or the relevant null is rejected at the 10, 5, and 1 percent level, respectively. See Table 1 for the definition of variables.

Mediating effects

Following the mediating effect test method proposed by Zhang and Ma (2021), we check the mediating mechanism of the relationship between DTG and corporate carbon emission intensity, and the results are reported in Table 7. In column (1), *DTG* and low-carbon innovation have a U-shaped relationship. Model 2 shows that the impact of DTG^2 on corporate carbon emission intensity is still significant after adding low-carbon innovation. The coefficient of *Lowinno* is -2.0121 and is significant at the level of 1%, which suggests that low-carbon innovation is a partial mediator between DTG and corporate carbon emission intensity. Hypothesis 4 is confirmed. We find that low-to-moderate DTG is associated with lower levels of low-carbon innovation and higher corporate carbon emission intensity. With the increase in DTG, the level of low-carbon innovation gradually improves, and effectively reduces corporate carbon emission intensity. Therefore, besides corporate economic performance, DTG also decreases corporate carbon emission intensity through low-carbon innovation.

Table 7 Mediating effect of low-carbon innovation.

Variable	*Lowinno*	*LnRin*
	(1)	(2)
DTG	-0.1185*** (0.0265)	1.0506*** (0.2454)
DTG²	0.0064*** (0.0021)	-0.0484** (0.0212)
Lowinno		-2.0121*** (0.7402)
Control variables	YES	YES
Firm fixed effect	YES	YES
Year fixed effect	YES	YES
N	830	830

R^2	0.7385	0.6692

Notes: The dependent variable in the regression is *LnRin*. *LnRin* is carbon emissions per revenues. All the estimations have controlled for firm fixed effects and year fixed effects. The standard errors robust to heteroscedasticity, clustered by firm level, are reported in the parentheses. (*), (**) and (***) indicates that the coefficients are significant or the relevant null is rejected at the 10, 5 and 1 percent level, respectively. See Table 1 for the definition of variables.

Discussion and conclusion

This study provides evidence of the relationship between DTG and corporate carbon emission intensity, using unbalanced panel data. With a sample of U.S. 608 listed corporations for 2009-2018 from CDP, we find that DTG has an inverted U-shaped relationship with corporate carbon emission intensity We find that DTG has a significant impact on corporate carbon emission intensity. In Hypothesis 1, our results support the inverted U-shaped relationship between DTG and corporate carbon emission intensity for the first test. In Hypothesis 2 and Hypothesis 3, we discuss the boundary conditions between the two through team size and gender diversity. We argue team size and gender diversity has a positive moderating effect at the left of inverted U-shaped curve, and the larger team size, the better moderating effect (Hernández et al., 2020; Zaid et al., 2020; Corvino et al., 2019; Perryman et al., 2016). Meanwhile, team size and gender diversity have a negative moderating effect at the right of inverted U-shaped curve, and the larger team size, the worse moderating effect (Orazalin and Baydauletov, 2020; Orazalin and Baydauletov, 2020; Munjal et al., 2019; Leal-Rodríguez et al., 2015). Further, we find the optimal team size is 8-11 members (Ogungbamila et al. 2010; Rodríguez et al., 2012; Katzenbach and Smith, 1993), and the optimal number of women members is 3-4 women members (Cabeza-García et al., 2018). In Hypothesis 4, our results find that low-carbon innovation is an efficient channel for DTG to decrease corporate carbon emission intensity.

Theoretical implications

Firstly, we fill an important gap in the literature by exploring DTG influence patterns on corporate carbon emission intensity. Based on group development theory and social identity theory, we propose two potential functions between DTG and corporate carbon emission intensity. One is a negative linear function under low-to-moderate stages of team development.

Due to the low team identity, team members have low levels of team psychological safety climate, which fails to effectively decrease corporate carbon emission intensity. The other is a positive linear function under the late stage of team development. The high team identity promotes team members to have a higher consistency, which improves performance and decreases corporate carbon emission intensity.

Furthermore, our study contributes to a greater understanding of the antecedents of corporate carbon emission intensity from corporate governance, particularly highlighting the roles played by DTG in decreasing corporate carbon emission intensity. How teams play a governance role is a crucial question in decreasing corporate carbon emission intensity. This study extends the prior literature to illustrate the importance of DTG in decreasing corporate carbon emission intensity in terms of both team size and gender diversity. Based on the perspective of team development, by combining social identity theory and resource dependence theory, we engage in a more in-depth discussion of what team size and gender diversity characteristics of a team can decrease corporate carbon emission intensity, which has rarely been addressed in traditional team effectiveness literature. We find that when adding the moderating variable of team size and gender diversity in the equation between DTG and corporate carbon emission intensity, the inflection point of the inverted U-shaped curve moves to the left, indicating that team size and gender diversity advance the effective of DTG. A shorter DTG leads to greater conflict and higher corporate carbon emission intensity. team size and gender diversity moderate the inverted U-shaped relationship by weakening the negative effect of DTG. A longer DTG has better coordination ability, and team size and gender diversity prolong the effective term of DTG by weakening the positive effect of DTG.

Finally, we extend the application of resource dependence theory in teams. Innovation is the main driver for low-carbon development. When team identity is low, members are less likely to engage in radical innovation behaviors, and insufficient resources to drive innovative decisions. The increase in DTG also accumulates team's resources for environmental awareness and environmental innovation. High team identity and resource accumulation exert a positive influence on team's innovation behavior. Besides, team members will also achieve high performance by adopting low-carbon innovative approaches.

Managerial implications

Our findings also have important implications for managerial practice on DTG and corporate environmental performance. Gonzalez-Mulé et al. (2020) argue that newly formed teams need to build shared experience in order to gain trust in one another, and figure out their contribution to team functioning. With the efforts that need to be expended in these directions, such teams could have less team cohesion and efficacy. Thus, in team governance, corporations need to fully take team members' run-in time into account. Innovation can give corporations a competitive edge. Team members' oneness with and belongingness exert a positive influence on innovation behavior, which can promote team performance and highlight the benefits of DTG. We argue that the effectiveness of DTG can be improved by low-carbon innovation. Thus, in the selection of team members, the focus should be on selection members who have consistent cognitive same to the intended team governance outcomes to achieve the best DTG performance.

Team size and gender diversity can help teams shorten the run-in period. The increase in team size can bring more resources such as time, experience and expertise for team decision-making to reduce the harm caused by one-sided decisions. However, larger sizes also lead to cumbersome coordination and communication and free-riding behavior. Small groups and faultlines resulting from larger teams lead to lower governance. Gender diversity brings greater collaboration, nurturing and resource sharing. A high degree of independence in women decision-making neutralizes the aggressive collaborative atmosphere of men members. Low gender diversity can lead to women being excluded from the "old boys" network and impede women's voices. High gender diversity is also not conducive to role congruity in teams. Thus, we find that in teams dealing with climate change, the optimal number of team members is 8-11 people, and the number of women members is 3-4 people.

Limitations and future research

Our study is subject to several limitations that indicate potential avenues for future research. Firstly, the background and culture of teams may affect the decision of corporate managers. In this study, we do not consider the external environment, such as the corporate background and culture and its potential impact on DTG. Therefore, we may try to study the influence of corporate culture or background on DTG in future research, and further study the effectiveness of DTG in the same culture and background. Secondly, our study is limited to a particular team. The reduction of corporate carbon emission intensity requires the synergistic effect of multiple departments and teams within the corporation. Performance impacts vary with the stakeholder focus, team resource availability, and the industry sustainability landscape. We only find a specific path between DTG and corporate carbon emission intensity. Future research can explore whether cooperation between multiple departments and teams within corporations is more conducive to decreasing corporate carbon emission intensity. We can also try to study the impact of specific teams of corporations addressing climate change, such as the Sustainable Development Committee, on the impact of corporate carbon emission intensity. And examine whether sustainable development is related to the large-scale applications of low-carbon technologies or internal carbon pricing.

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Appendix

Appendix 1 The moderating effect of size with member numbers of 1 to 31 in the sample.

Variable	*LnRin*									
	1 team member	2 team members	3 team members	4 team members	5 team members	6 team members	7 team members	8 team members	9 team members	10 team members
DTG	-0.0013	0.0588	0.0502	0.0502	-0.0110	-0.0110	-0.0144	0.5082**	0.5035**	0.5675**
	(0.6391)	(0.5894)	(0.5493)	(0.5493)	(0.5366)	(0.5366)	(0.4753)	(0.2394)	(0.2303)	(0.2490)
DTG^2	0.0135	0.0064	0.0075	0.0075	0.0159	0.0159	0.0164	-0.0505**	-0.0500**	-0.0630**
	(0.0783)	(0.0725)	(0.0679)	(0.0679)	(0.0674)	(0.0674)	(0.0581)	(0.0254)	(0.0246)	(0.0252)
Tamount×DTG	0.3772	0.3133	0.3229	0.3229	0.3869	0.3869	0.3903	-0.4283*	-0.4238**	-0.4159*
	(0.6316)	(0.5752)	(0.5298)	(0.5298)	(0.5211)	(0.5211)	(0.4662)	(0.2174)	(0.2076)	(0.2235)
Tamount ×DTG^2	-0.0418	-0.0344	-0.0356	-0.0356	-0.0438	-0.0438	-0.0442	0.0478**	0.0473**	0.0521**
	(0.0775)	(0.0714)	(0.0665)	(0.0665)	(0.0660)	(0.0660)	(0.0571)	(0.0237)	(0.0229)	(0.0238)
Tamount	-0.6973	-0.5954	-0.6132	-0.6132	-0.6856	-0.6856	-0.6859	0.5314	0.5241	0.3088
	(0.9610)	(0.8653)	(0.7919)	(0.7919)	(0.7507)	(0.7507)	(0.7477)	(0.3661)	(0.3362)	(0.4157)
Control variables	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Firm fixed effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	3460	3460	3460	3460	3460	3460	3460	3460	3460	3460
R^2	0.1856	0.1840	0.1851	0.1851	0.1878	0.1878	0.1878	0.1319	0.1321	0.0942

Variable	*LnRin*									
	11 team members	12 team members	13 team members	14 team members	15 team members	16 team members	17 team members	18 team members	19 team members	20 team members
DTG	0.5617**	0.3833	0.7337*	0.7337*	0.5152*	0.5476*	0.5710***	0.2638	0.3250*	0.4988**
	(0.2519)	(0.2399)	(0.4108)	(0.4108)	(0.2953)	(0.2899)	(0.2110)	(0.2001)	(0.1667)	(0.2179)
DTG^2	-0.0624**	-0.0413*	-0.0800*	-0.0800*	-0.0431	-0.0447*	-0.0472***	-0.0422*	-0.0253*	-0.0328
	(0.0255)	(0.0231)	(0.0433)	(0.0433)	(0.0281)	(0.0263)	(0.0167)	(0.0249)	(0.0149)	(0.0209)
Tamount ×DTG	-0.4098*	-0.2276	-0.5871	-0.5871	-0.1703	-0.2081	-0.2390	-0.2124	-0.1876	-0.1698
	(0.2250)	(0.2051)	(0.3966)	(0.3966)	(0.2773)	(0.2520)	(0.1687)	(0.2048)	(0.1402)	(0.1591)
Tamount ×DTG^2	0.0516**	0.0302	0.0703	0.0703	0.0164	0.0183	0.0215	0.0278	0.0160	0.0062
	(0.0240)	(0.0210)	(0.0428)	(0.0428)	(0.0280)	(0.0256)	(0.0164)	(0.0251)	(0.0143)	(0.0194)
Tamount	0.2931	0.1545	0.0155	0.0155	0.1457	0.2881	0.3373	0.3434	0.2788	0.2515
	(0.4170)	(0.4278)	(0.4954)	(0.4954)	(0.4878)	(0.4318)	(0.3345)	(0.2437)	(0.2449)	(0.1939)
Control variables	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Firm fixed effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	3460	3460	3460	3460	3460	3460	3460	3460	3460	3460
R^2	0.0941	0.0922	0.1009	0.1009	0.1789	0.1815	0.1849	0.1619	0.0960	0.2050

Variable	*LnRin*										
	21 team	22 team	23 team	24 team	25 team	26 team	27 team	28 team	29 team	30 team	31 team

	members	members	members	members	members	members	members	members	members	members	members
DTG	0.5181**	0.4396**	0.4847**	0.4261**	0.4093**	0.3796**	0.3587**	0.3530**	0.3230**	0.3357**	0.3137**
	(0.2146)	(0.2009)	(0.1873)	(0.1671)	(0.1668)	(0.1560)	(0.1523)	(0.1512)	(0.1494)	(0.1425)	(0.1387)
DTG^2	-0.0374*	-0.0300*	-0.0374**	-0.0326**	-0.0320**	-0.0291**	-0.0276**	-0.0280**	-0.0241**	-0.0258**	-0.0230**
	(0.0194)	(0.0173)	(0.0161)	(0.0139)	(0.0140)	(0.0123)	(0.0117)	(0.0116)	(0.0115)	(0.0108)	(0.0103)
Tamount ×DTG	-0.1926	-0.1089	-0.1749	-0.0936	-0.0752	-0.0613	-0.0387	-0.0039	0.0755	0.0899	0.1557
	(0.1518)	(0.1358)	(0.1318)	(0.1175)	(0.1258)	(0.1183)	(0.1243)	(0.1199)	(0.1289)	(0.1337)	(0.1323)
Tamount ×DTG^2	0.0117	0.0028	0.0135	0.0074	0.0070	0.0050	0.0040	0.0025	-0.0087	-0.0093	-0.0187
	(0.0180)	(0.0163)	(0.0152)	(0.0136)	(0.0147)	(0.0138)	(0.0137)	(0.0133)	(0.0137)	(0.0141)	(0.0141)
Tamount	0.2050	0.2084	0.1131	-0.0297	-0.0973	0.0990	0.1469	-0.0247	-0.0334	-0.2326	-0.1890
	(0.1906)	(0.1928)	(0.2050)	(0.2219)	(0.2213)	(0.1457)	(0.1444)	(0.1540)	(0.1684)	(0.1784)	(0.2290)
Control variables	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Firm fixed effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	3460	3460	3460	3460	3460	3460	3460	3460	3460	3460	3460
R^2	0.1974	0.1941	0.1908	0.1849	0.1839	0.1784	0.1791	0.1783	0.1786	0.1802	0.1828

Notes: The dependent variable in the regression is *LnRin. LnRin* is carbon emissions per revenues. All the estimations have controlled for firm fixed effects and year fixed effects. The standard errors robust to heteroscedasticity, clustered by firm level, are reported in the parentheses. (*), (**) and (***) indicates that the coefficients are significant or the relevant null is rejected at the 10, 5 and 1 percent level, respectively. See Table 1 for the definition of variables.

Appendix 2 The moderating effect of the number of women members from 7 to 12 in the sample. Few teams have more than 12 women members and we cannot report on the return results, so here we report only the moderating effect of teams with 12 or fewer women members.

Variable	*LnRin*					
	1 woman member	2 women members	**3 women members**	**4 women members**	5 women members	6 women members
DTG	0.3271**	0.3473**	**0.8186****	**0.5641*****	0.3619**	0.3679**
	(0.1555)	(0.1547)	**(0.3242)**	**(0.1037)**	(0.1629)	(0.1545)
DTG^2	-0.0239**	-0.0269**	**-0.0797*****	**-0.0416*****	-0.0268**	-0.0298***
	(0.0112)	(0.0110)	**(0.0254)**	**(0.0097)**	(0.0119)	(0.0106)
Gamount×DTG	0.2660	0.0294	**-0.5732****	**-0.2071***	-0.1259	-0.2908
	(0.1814)	(0.1717)	**(0.2855)**	**(0.1109)**	(0.0869)	(0.2600)
Gamount×DTG^2	-0.0130	-0.0017	**0.0673****	**0.0319****	0.0062	0.0369
	(0.0209)	(0.0197)	**(0.0330)**	**(0.0135)**	(0.0124)	(0.0339)
Gamount	-0.5058***	0.0923	**0.4335**	**0.1443**	0.1790	0.2867
	(0.1796)	(0.2051)	**(0.5666)**	**(0.1950)**	(0.1397)	(0.3104)
Control variables	YES	YES	**YES**	**YES**	YES	YES
Firm fixed effect	YES	YES	**YES**	**YES**	YES	YES
Year fixed effect	YES	YES	**YES**	**YES**	YES	YES
N	3460	3460	**3460**	**3460**	3460	3460
R^2	0.1913	0.1790	**0.6455**	**0.4552**	0.1853	0.1905

Variable	*LnRin*					
	7 women members	8 women members	9 women members	10 women members	11 women members	12 women members
DTG	0.1709	0.0644	-0.0288	0.1058	0.1622	0.3515**
	(0.1098)	(0.0863)	(0.0584)	(0.1442)	(0.1072)	(0.1551)
DTG^2	-0.0131	-0.0015	-0.0029	-0.0074	-0.0116	-0.0270**
	(0.0084)	(0.0075)	(0.0057)	(0.0119)	(0.0082)	(0.0109)
Gamount×DTG	-0.1585	-0.1711	-0.0729	-0.0376	-0.3397	-0.0103
	(0.1481)	(0.1796)	(0.9097)	(0.4995)	(0.3403)	(0.0377)
Gamount×DTG ^{2}	0.0305	0.0052	0.0348	0.0371	0.0392	0.0000
	(0.0193)	(0.0166)	(0.1131)	(0.0648)	(0.0452)	(.)

Gamount	0.1257	0.7333**	-0.3214	-0.7292	0.0000	0.0000
	(0.1483)	(0.3213)	(0.2319)	(0.8069)	(.)	(.)
Control variables	YES	YES	YES	YES	YES	YES
Firm fixed effect	YES	YES	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES	YES	YES
N	3460	3460	3460	3460	3460	3460
R^2	0.1782	0.1417	0.1284	0.2899	0.0914	0.1773

Notes: The dependent variable in the regression is *LnRin*. *LnRin* is carbon emissions per revenues. All the estimations have controlled for firm fixed effects and year fixed effects. The standard errors robust to heteroscedasticity, clustered by firm level, are reported in the parentheses. (*), (**) and (***) indicates that the coefficients are significant or the relevant null is rejected at the 10, 5 and 1 percent level, respectively. See Table 1 for the definition of variables.

Appendix 1 The number of corporations in various industries in the sample and the average duration of firms adopting team governance and observations in various industries.

Industry	**Number of sample firms**	**The average duration**	**Observations**
1. Apparel	6	3.5	36
2. Biotech, health care & pharma	42	4.4	281
3. Food, beverage & agriculture	40	4.43	249
4. Fossil Fuels	26	3.96	138
5. Home building	1	0	1
6. Hospitality	16	2.32	102
7. Infrastructure	34	3.12	174
8. Manufacturing	200	2.94	1065
9. Materials	5	4.6	23
10. Metals Mining	5	2.8	19
11. Mineral extraction	1	3	10
12. Power generation	13	3.77	87
13. Retail	30	4.23	205
14. Services	172	3.02	970
15. Transportation services	11	4.18	71
16. Cannot be classified	7	1.43	29

Appendix 2 The average revenue intensity, average employee intensity, average total emissions, average Scope 1 emissions, average Scope 2 emissions of establishment of corporates in various industries in the sample.

Industry	**Average revenue intensity (MTCO2e/ revenues)**	**Average employee intensity (MTCO2e/full-time employees)**	**Average total emissions (MTCO2e)**	**Average Scope1 emissions (ST1CO2e/ revenues)**	**Average Scope2 emissions (ST2CO2e/ revenues)**
1. Apparel	300528.997	799433.067	183327.014	1099962.083	386569.769
2. Biotech, health care & pharma	1881151.483	1889466.05	3771417.271	151428.876	154524.675
3. Food, beverage & agriculture	6085294.703	3586310.825	9626567.49	1842040.265	1878470.185
4. Fossil Fuels	95821118.785	9803475.426	106227034.823	3461193.389	3441230.487

5. Home building	1177	19119	20296	28.871	507.4
6. Hospitality	5694682.438	7138409.081	12836176.206	5596012.021	5585673.661
7. Infrastructure	111506903.764	4709127.421	116523918.653	12405980.328	12372389.017
8. Manufacturing	4401667.549	5141712.328	9537177.857	1921798.402	1909806.893
9. Materials	13366216	7160833.4	20674665.6	8187269.281	8230835.309
10. Metals Mining	94031650.4	31047934	124809258.4	60558916.053	60537447.646
11. Mineral extraction	36800000	12920000	49900000	126622.66	220929.9
12. Power generation	231185923.031	3772899.234	234954197.731	52045619.650	52186497.91
13. Retail	3944536.549	11405747.833	15352391.129	1922640.308	1927056.939
14. Services	3122290.703	1351777.301	4494952.435	413735.357	413897.284
15. Transportation services	90769156.258	1014738.245	91587964.591	5178613.982	5220401.104
16. Cannot be classified	6300994.809	998759.2	7287371.986	38956.320	42262.11

Appendix 3 The average Scope 1 revenue intensity, average Scope 2 revenue intensity, average Scope 1 employee intensity and average Scope 2 employee intensity of establishment of corporations in various industries in the sample.

Industry	**Average Scope 1 Revenue intensity (ST1CO2e/ revenues)**	**Average Scope 2 Revenue intensity (ST2CO2e/ revenues)**	**Average Scope 1 Employee intensity (ST1CO2e/full-time employees)**	**Average Scope 2 Employee intensity (ST2CO2e/full-time employees)**
1. Apparel	125924.641	43444.652	260667.912	260563.029
2. Biotech, health care & pharma	43796.406	107673.995	45126.048	109469.652
3. Food, beverage & agriculture	1040024.993	800743.404	1058014.206	819800.489
4. Fossil Fuels	3185112.047	284974.193	3166429.819	284650.860
5. Home building	1.674	27.952	29.425	490.231
6. Hospitality	1220996.321	4412339.584	1214407.209	4408663.503
7. Infrastructure	11920969.026	502706.056	11885612.967	507401.935
8. Manufacturing	949573.183	978140.325	942333.488	973213.484
9. Materials	5844452.407	2282884.058	5869713.816	2301577.506
10. Metals Mining	52829738.951	7580447.727	52815963.888	7572404.493

11. Mineral extraction	99193.62	26681.731	160890.1	60957.536
12. Power generation	51961010.397	256321.301	52097165.190	261116.376
13. Retail	557301.577	1350998.401	558384.617	1354562.758
14. Services	48931.176	363161.166	48823.673	363475.870
15. Transportation services	5164649.210	15832.644	5206362.333	15914.209
16. Cannot be classified	14910.234	24087.654	17585.298	24745.726