// NO.24-063 | 10/2024

DISCUSSION PAPER

// HELENA LENIHAN, MAURICIO PEREZ-ALANIZ,
AND CHRISTIAN RAMMER

Climate Action Response Plans in Firms: Understanding the Characteristics of Firms Planning for a More Sustainable Future

Leibniz Association

ZEW

Climate Action Response Plans in Firms: Understanding the Characteristics of Firms Planning for a More Sustainable Future

Helena Lenihan[1*], Mauricio Perez-Alaniz[1], and Christian Rammer[2]

October 2024

Abstract

Firm-level Climate Action Response Plans (CARPs) are strategic plans comprising firms' climate change mitigation and adaptation commitments. Given the importance of CARPs for meeting climate change targets, encouraging firms to develop CARPs is paramount. When designing evidence-based approaches to drive firm-level CARPs, it is essential to know the resources and capabilities that enable firms to develop CARPs. Drawing on novel and highly detailed data on firms in Ireland, and using a direct matching approach, our study examines the characteristics that distinguish firms that develop and do not develop CARPs. We find that firms developing CARPs: (1) Exhibit strong market performance, in terms of productivity and sales; (2) Engage in international markets; (3) Are highly R&D and innovation active; and (4) Already use digital technologies. Such insights suggest that CARPs require firms to have high levels of resources and skills when designing their responses to climate change. The paper proffers potential policy and managerial implications, in terms of encouraging firms to develop CARPs.

Keywords: Firm-level climate action, Climate Action Response Plans, Climate Change Adaptation, Climate Change Mitigation; Firms' R&D and innovation, Greenwashing

JEL: Q54, Q56, Q57, L21, L25, M14

[1] Department of Economics, Kemmy Business School, University of Limerick, Limerick, Ireland (Helena.Lenihan@ul.ie; Mauricio.PerezAlaniz@ul.ie)

[2] Department of Economics of Innovation and Industrial Dynamics, ZEW - Leibniz-Centre for European Economic Research, Mannheim, Germany (rammer@zew.de)

* Corresponding author

1. Introduction

Given the urgent global need to respond to climate change, firms are under increasing pressure to accelerate their climate change mitigation and adaptation efforts (Amar et al. 2023). At the firm level, climate change mitigation entails reducing carbon emissions and aligning business practices with climate goals (Lainé 2023). Adaptation refers to firms taking stock of and responding to the risks of climate change (Hampton et al. 2023). Developing a firm-level Climate Action Response Plan (CARP) is a critical first step for firms engaging in climate change mitigation and adaptation activities (Johnson et al. 2023; CDP 2024). Also known as Climate Transition Plans, CARPs are time-bound plans outlining how firms intend to align strategies, assets, operations, and business activities, to mitigate and adapt to climate change (Kouloukoui et al. 2021; CDP 2024). They are critical for firms moving beyond "conventional corporate responses to climate change", and "effectively respond to the current challenges of deep decarbonization" (Johnson et al. 2023, p. 921). As the Carbon Disclosure Project (CDP) outlines, "there is a pressing need to further define credible actions and support progress, particularly in transition planning" (CDP 2024, p. 5). Importantly, our understanding regarding the extent to which firms are developing CARPs, and especially, the characteristics of firms leading such efforts, remains very limited (Littlewood et al. 2018; Johnson et al. 2023). This is a critical gap in existing knowledge, as it is only when this has been clearly established, can policymakers truly focus (in an evidence-based way) to deploy policy efforts to encourage firms to do more in this regard. Our paper addresses this gap, by answering the following research question: *What are the key characteristics that empirically distinguish firms that develop and do not develop CARPs*?

By addressing the above question, we advance a pressing research agenda regarding the actions firms carry out to mitigate and adapt to climate change. We make three key contributions. Our first contribution is to outline how CARPs can serve as a critical tool for encouraging deeper and holistic climate action in firms. By holistic, in this context, we mean considering both climate change mitigation and adaptation activities. This is important, because firms mainly focus on climate change mitigation, as opposed to adaptation (Walenta 2020). Firms also tend to follow an economic imperative when engaging in mitigation activities, placing their prime focus on economic returns (Fremstad and Paul 2022; Le Ravalec et al. 2022). Thus, the oft prevailing criticism that firms primarily engage in 'greenwashing' as opposed to proactive climate action efforts *per se.* Such greenwashing occurs when firms capitalise on their climate promises, despite not following through with them (Coen et al. 2022). As articulated by Walenta (2020), given firms' combined presence and influence in climate action efforts, "sustained research on their role is much needed" (p. 3). We

contribute to this research agenda, by discussing how firm-level CARPs can result in more impactful climate change mitigation and adaptation activities and reduce greenwashing.

Our second contribution relates to the fact that to date, firm-level empirical studies have primarily focused on specific and individual activities that firms carry out to mitigate and/or adapt to climate change, as opposed to taking a more holistic view. Such studies have mainly focused on key mitigation strategies, such as whether firms implement environmental resource-efficient technologies (Aldieri et al. 2022), or whether they engage in corporate social responsibility and environmental disclosure activities (Karim et al. 2021). For Littlewood et al. (2018), only a few studies have considered the extent to which firms engage in climate action in an 'integrative' (holistic) way. Our focus on CARPs brings together critical insights from the above largely independent strands of the literature regarding climate action in firms, to take a holistic account of firms' climate change adaptation and mitigation efforts. This matters, given the increasing urgency for firms to adhere to global climate targets, organise their resources and capabilities to achieve these targets, and disclose the performance impacts of such actions (Schöller and Ulmer 2023).

Our third contribution is to undertake an in-depth empirical analysis of the characteristics that distinguish firms that have and have not developed CARPs. We achieve this by using a very rich database, beyond the level of detail provided by studies heretofore. There has been little consideration by previous studies to the characteristics of firms developing (not developing) CARPs, besides analyses by firm-sizes and sectors. We extend such previous analyses, by considering a comprehensive set of variables measuring firms' economic performance, R&D and innovation activities, and other key characteristics influencing how firms operate. To the best of our knowledge, this is the first time that such a comprehensive analysis is carried out. Moreover, the limited existing evidence on this topic has been mostly based on data from the Carbon Disclosure Project (CDP). Although rich in terms of including data on firms from many countries, these data mainly comprise global Multinational Enterprises (MNEs) and large-sized firms, meaning that Micro, Small and Medium Sized Enterprises (MSMEs), the backbone of most economies, are not covered by previous studies on this topic (Backman et al. 2015; Blanco et al.

2020).[1] This is a key limitation, given that, writing in the context of SMEs, Hampton et al. (2023) have argued that such firms "have been largely neglected by climate policies across all levels of government" (p. 1). This is despite SMEs, including micro-firms, being "generally less prone than large enterprises (LEs) to undertake transformational changes and appear limitedly conscious of their impact on the environment and society" (Negri et al. 2021, p. 2). Our study overcomes the data limitations associated with previous studies by drawing on unique firm-level data, comprising information regarding environmental, innovation, and performance measures of firms in Ireland. Unlike previous studies on this topic, the data available to the current paper permit considering both MSMEs, large firms, MNEs and domestic firms.

Our analysis is based on a sample of 1,959 firms, with 460 firms (i.e. 23.4 percent) having developed, and 1,499 having not developed CARPs. To undertake our analysis, we use an exact propensity score matching approach. We specifically match firms according to their environmental footprints, as measured by their energy intensity, and the extent to which they recognise the importance of having CARPs in place, amongst other key characteristics. While some of these matched firms developed CARPs, other firms did not. Following this, we carry out a deep-dive empirical examination of the characteristics associated with firms developing and not developing CARPs, using our matched sample. This is important because, as Kouloukoui et al. (2021) note, firm-level heterogeneities affect firms' levels of exposure to climate-related risks and can result in different levels of climate responses. Our approach thus permits comparing 'like with like'.

From a policy perspective, our paper proffers critical insights, with the potential of informing the design and implementation of specific policy actions and interventions to encourage firms to develop CARPs. For Westman et al. (2021, p. 108), despite significant policy efforts to encourage firms to adopt deeper climate efforts, firms existing climate efforts are only "producing incremental improvements or even cementing the status quo". In turn, some recent studies highlight the need for more targeted policy efforts, to encourage firms to enhance their existing climate change mitigation and adaptation efforts (Hampton et al. 2023; Johnson et al. 2023). Yet, in line with

[1] The European Union recommendation 2003/361 defines small-sized firms as firms with less than 50 employees, medium- sized firms as firms between 50 and 249 employees, and large-sized firms as firms with 250 employees or more. The recommendation also classifies firms according to their turnover or balance sheet (see http://data.europa.eu/eli/reco/ 2003/361/oj), but the number of employees is the most commonly used classification (OECD 2019). Micro-firms are typically small-sized firms with fewer than 10 employees.

Anderson et al. (2023), designing and implementing such policies requires first understanding the specific target population, to ensure that they are economically, socially, and politically viable.

The remainder of the paper is structured as follows: Section 2 focuses on firm-level CARPs for firms mitigating and adapting to climate change. Section 3 discusses the data and empirical approach. Section 4 discusses the main empirical characteristics that distinguish those firms that developed and did not develop CARPs. Finally, Section 5 concludes by discussing our results, considering existing studies concerned with encouraging firm-level climate action, along with a discussion of the policy and managerial implications of our findings.

2. Firm-level climate action response plans

2.1 The importance of firm-level climate action response plans

Firms are key climate actors, and there is an ever-pressing need for firms to intensify their climate change mitigation and adaptation efforts to meet existing climate targets (Karim et al. 2021; Schöller and Ulmer 2023). In this context, previous studies have shown that firms mainly engage in climate action if they can expect cost reduction, improved performance and/or competitive advantage (Coen et al. 2022; Hampton et al. 2023). The increasing awareness of climate change-related issues by consumers and investors can potentially result in firms internalising some of the benefits of their climate change mitigation and adaptation activities (Backman et al. 2015). Yet, existing reporting and benchmarking mechanisms do not fully enable assessing which firms are truly engaging in climate efforts (Walenta 2020). Therefore, it is difficult for consumers and investors to distinguish between firms that actively engage in climate efforts, and firms engaging in greenwashing, by not following through with their climate promises (Coen et al. 2022).

Firm-level Climate Action Response Plans (CARPs) can enable firms to take stock of the opportunities and challenges associated with climate change and pursue holistic and coherent responses to climate change (Le Ravalec et al. 2022). Moreover, they can improve firm-level transparency and accountability in terms of climate action. This is because CARPs permit assessing whether firms are committing to climate change efforts, and the extent to which their actions are in line with these commitments (Walenta 2020; Johnson et al. 2023). CARPs can thus reduce greenwashing, as they can enable consumers and investors to clearly identify climate leaders and laggards. They can also provide effective market signals, and enable firms to better internalise their climate efforts, potentially creating new markets and sources of competitive advantage. Resultantly, CARPs can potentially enable firms to re-frame their investments in climate change

related activities over longer-term horizons, as opposed to only focussing on short-term investments (Blanco et al. 2020; Vollebergh 2023). Ultimately, this, can potentially re-shape the economic rationale driving climate efforts in firms.

2.2 Evidence of firms developing climate action response plans

The existing evidence regarding the drivers of firm-level CARPs is limited. A key reason for this is that firm-level studies have traditionally focused on the range of actions that firms carry out to mitigate and adapt to climate change, individually from each other. For example, studies have focused on firms improving the environmental performance of supply chains (Negri et al. 2021) or engaging in sustainability reporting (Johnson et al. 2023), amongst a plethora of other activities. As Littlewood et al. (2018, p. 1438) noted, "[t]o date, few studies have examined integratively, and using empirical data collected from practising managers, the drivers of and outcomes from corporate commitment to climate change action". Indeed, as we discuss below, only a handful of studies have focused on CARPs (i.e. Kouloukoui et al. 2021; De Abreu et al. 2021; Kren and Lawless 2023). Some other studies have also considered similar concepts to CARPs, including: (1) Climate Strategy Adoption (Ben-Amar et al. 2022); (2) Emission Reduction Plans (Blanco et al. 2020); (3) Climate Policies (Bose et al. 2022); (4) Proactive Environmental Strategies (Backman et al. 2015); and/or (5) Corporate Climate Strategy (Coen et al. 2022). However, most studies heretofore have primarily focused on firm-level impacts, in terms of environmental performance outcomes (e.g. carbon emissions), resulting from the above plans and strategies. These studies have not specifically focused on the characteristics of firms developing such plans, as we do in the current paper.

To the best of our knowledge, to date, only very few studies outline the drivers affecting the development of firm-level CARPs. Kouloukoui et al. (2021), for example, show that the intensity of firm-level carbon emissions, firm size, power of shareholders, and firms' countries of origin, are important determinants of firm-level CARPs. De Abreu et al. (2021), in turn, emphasise the role of environmental regulation and market dynamics. Bose et al. (2023) report that executive compensation linked to environmental performance drives environmental climate strategies in firms, as measured by the development of CARPs. Finally, Kren and Lawless (2023) outline the adoption of digital technologies (i.e. cloud computing, artificial intelligence) by firms, as an important precondition for the development of firm-level CARPs. These studies provide novel insights regarding the drivers of CARPs. Yet, they do not provide a detailed and comprehensive understanding of the specific characteristics of firms developing and not developing such plans. As alluded to earlier, the focus of the above studies (except for Kren and Lawless 2023) has been

primarily on large and/or multinational firms, given that these studies primarily draw on data from the Carbon Disclosure Project (CDP), and similar surveys focused on large-sized firms. While very rich in terms of the number of firms covered across countries, the predominance of large-sized firms in the CDP dataset is by now a well-known limitation of such data (Backman et al. 2015; Blanco et al. 2020). We contribute to addressing these issues, by providing an in-depth account of the characteristics distinguishing firms that develop and do not develop CARPs.

2.3 Characteristics of firms developing firm-level climate action response plans

In empirically analysing the key characteristics that distinguish firms that develop and do not develop CARPs, we conceptualise developing a CARP as similar to investing in intangible assets. Our conceptualisation is in line with studies by Russo and Fouts (1997), Gans and Hintermann (2013), and Albitar et al. (2023), which highlight the importance of firms investing in environmental action, as a means of developing environmental capabilities. A key reason underpinning our conceptualisation is that CARPs require investment in organisational resources, which do not immediately result in economic returns (De Abreu et al 2021; Bose et al. 2022). Developing CARPs can also result in positive spillovers, in terms of knowledge and improved environmental quality. This is very similar to the 'double externality' issue affecting firms' investment in green/environmental R&D (Rennings 2000).

Considering the above, like other types of investment in intangibles, most notably R&D and innovation, firms need in-house financial resources to finance CARP development activities (Montresor and Vezzani 2021). This is especially true for SMEs that typically have very limited access to external finance for investing in intangibles (Garrido-Prada et al. 2021). As firms' levels of internal financial resources are directly related to their market performance, the better a firm's performance in the market, the easier it will be for it to develop a CARP. As shown in the context of R&D and innovation, a strong market performance can also result in firms being more open to engage in more explorative and longer-term R&D activities (Perez-Alaniz et al. 2023). Developing a CARP also requires skills and in-house capabilities, which are similar to the capabilities needed for creating and applying new knowledge within the firm (Chatzistamoulou and Tyllianakis 2022). R&D and innovation are key avenues for firms to develop absorptive capacity (Cohen and Levinthal 1990). In turn, firms with extensive internal knowledge capabilities, and those that can identify and absorb external usable knowledge, will be better equipped to develop CARPs.

Developing a CARP is likely to be based on the use of digital tools to monitor and report climate actions, meaning that firms' levels of digital skills are likely to be key enabling factors for CARPs

(Chatzistamoulou 2023; Kren and Lawless 2023). Firms already using digital technologies and tools may thus be more likely to develop CARPs, than firms not using such technologies. Developing a CARP is also a key management decision (Littlewood et al. 2018). Therefore, to leverage the full potential of such a plan, the CARP must be well integrated into a firm's other strategic actions, including marketing, new product development, internationalisation, and investments (Albitar et al. 2023). Likely, firms with strong management capabilities and resources will find it easier to develop and utilise CARPs. Moreover, when developing CARPs, firms may decide to collaborate with external organisations, especially with Higher Education Institutions (HEIs), that could serve as an important entry point for accessing and developing new climate change related knowledge (Garrido-Prada et al. 2021). Finally, consumer preference is a major driver for firm-level engagement in climate related innovation (Horbach et al. 2012). Given the increasing climate sensitivity of individuals, public organisations, and business partners, firms are increasingly required to demonstrate climate responsiveness to compete in markets (Chatzistamoulou and Tyllianakis 2022). While this trend affects all firms, it is likely to be especially important for firms serving international markets (Ghisetti et al. 2021), and firms acting as suppliers for public sector organisations (Shadrina et al. 2022).

3. Data and empirical approach

3.1 Data

Our analysis uses a novel and detailed database with information on firms in Ireland, namely the Annual Business Survey of Economic Impact (ABSEI). This is an annual panel survey, conducted by Ireland's Department of Enterprise, Trade and Employment (DETE). Targeting approximately 4,000 firms annually, with a response rate of approximately 65 percent, the ABSEI survey is unique because it is obtained from a sample frame covering all firms that have ever engaged with any of Ireland's enterprise development agencies (DETE 2020).[2] Therefore, ABSEI is specifically designed to cover a large representative sample of the domestic and foreign-owned firms located in Ireland (Kren and Lawless 2023). For this paper, we specifically use the 2020 ABSEI survey wave. This is the first ABSEI survey wave that included key questions on firms' climate actions, including whether they developed CARPs, in addition to detailed firm-level information. It is also

[2] The ABSEI survey specifically includes all client firms of Enterprise Ireland and the Industrial Development Agency Ireland (IDA). The former agency supports domestic (Irish) companies, whereas the latter agency's primary objective is to support investment into Ireland by foreign-owned companies.

the latest wave available to this study. Our sample comprises 3,063 firms that responded to the 2020 ABSEI survey wave. From these, we specifically focus on 1,959 firms that responded to at least two previous waves of the ABSEI survey since 2010, allowing us to measure the firm characteristics discussed in Section 2.3 above. Of these 1,959 firms, 460 firms (i.e. 23.4 percent) have developed CARPs, while 1,499 have not.

3.2 Empirical approach

In identifying the characteristics of firms that develop and do not develop CARPs, we consider issues of endogeneity resulting from simultaneity and reverse causality. This is because firms experiencing climate change-related challenges have specific incentives to develop CARPs (Amar et al. 2023). The same is likely true for environmental resource-intensive firms, and firms operating in highly regulated markets (Dewick et al. 2019). We do this using a two-stage approach. In the first stage, we use Propensity Score Matching (PSM) to construct a sample of firms that have developed CARPs, and firms that have not developed CARPs, but that share a similar set of underlying key characteristics to the first group of firms. PSM is widely used in evaluation studies focused on identifying the impacts that a given intervention has on firm-level outcomes (Vanino et al. 2019; Lenihan et al. 2024). As demonstrated by Klingebiel and Rammer (2020), PSM can also be used as a sample construction methodology. In the specific case of Klingebiel and Rammer (2020), their study seeks to understand the characteristics of firms that decide to continue or discontinue innovation projects. Before exploring a comprehensive set of firm-level characteristics, the authors propose that factors affecting such a decision will be different for firms of different sizes and/or industrial sectors. The number of innovation projects that firms engage with, is also noted as a key factor. Therefore, PSM is used to ensure that these key characteristics are balanced in the working sample. Our approach is similar to that of Klingebiel and Rammer (2020), but applied to the context of CARPs.

To implement our PSM approach, we estimate firms' probabilities to develop CARPs with the following probit model:

$$CARP_{kit} = \beta_0 + \beta_1 x_{it-1,2} + \varepsilon_{it} \qquad (1)$$

Where $CARP_{kit}$ is a dummy variable measuring whether firm *k* developed CARP *i* in period *t*. The term $x_{it-1,2}$ is a set of key underlying characteristics affecting firms' probabilities to develop CARPs, during two previous waves of the ABSEI survey as discussed below, in Section 3.3. The associated coefficient β_1 captures the extent to which these key underlying characteristics

influenced firms' decisions to develop/not develop CARPs. Table A1 in the Supplementary Material accompanying this paper presents the results of the probit estimation of Equation (1).

By estimating Equation (1), we obtain a propensity score for each firm, which represents a firm's probability to develop CARPs. We then match firms with similar propensity scores using an exact matching procedure, in a similar way to that of Vanino et al. (2019) and Lenihan et al. (2024). This is in the sense that we only allow matches between: (1) Firms of the same size category; (2) Firms from the same sector; and (3) Firms located in the same region. Moreover, we implement a nearest neighbour matching approach, with a narrow caliper of 0.2 points of the standard deviation of the propensity scores (Austin 2011). Our main analysis follows Caloffi et al. (2022), by matching each firm with three control firms (i.e. 1:3 matching). To test our results across different matching strategies, we use a 1:1 nearest neighbour matching approach.

Following the implementation of PSM, our second step is to compare firms that developed and that did not develop CARPS, across a series of key firm-level characteristics, as discussed in Section 2.3 (with the variables explained below in Section 3.3). We achieve this by estimating Equation (2):

$$E(aTTe_{ij}) = E(Y_{ij}|CARP = 1, X = x) - E(Y_{ij}|CARP = 0, X = x) \quad (2)$$

In the context of our study, aTTe in Equation (2) denotes whether there is any statistically significant difference in the characteristics *i (i= i….k)* between firms that developed CARPs (i.e. $Y_{ij}|CARP = 1, X = x$), and firms that did not develop CARPs ($Y_{ij}|CARP = 0, X = x$.) We estimate Equation (2) by a simple comparison of means (i.e. a t-test).

3.3 Key variables

Our main dependent variable is a binary variable measuring whether (or not) firms developed CARPs. This variable is obtained from a question in the 2020 ABSEI survey wave, regarding whether firms have developed CARPs. Specifically, the question is posed as follows: *Have you developed a climate action response for your business*? Firms are required to select one of the following three options: (1) Yes; (2) No; and (3) Don't know. Using this information, we construct a binary variable that equals 1 if firms responded 'Yes' to this question, and 0 if firms responded

'No'. Firms that responded 'Don't Know' are excluded from the analysis.[3] As Vollebergh (2023) notes, a necessary first step when implementing CARPs is firms measuring the environmental impacts of their operations. Therefore, as an additional analysis, we use a second binary dependent variable, capturing whether firms measured their CO_2 emissions. We base this variable on a specific question also contained in the 2020 ABSEI survey wave, which is posed in a similar way, to that of the above question pertaining to CARPs.

Table 1: Variables used in the Matching Process

Variables for Matching	Definition
Micro Firm < 10 employees	Binary Variable = 1 if firms have fewer than 10 employees, otherwise = 0.
Small Firm 10-19 employees	Binary Variable = 1 if firms have between 10-19 employees, otherwise = 0.
Small Firm 20-49 employees	Binary Variable = 1 if firms have between 20-49 employees, otherwise = 0.
Sector	Categorical Variable with Sectors as defined in the ABSEI Survey: 1. Business Financial and Other Services 2. Energy, Water, Waste and Construction 3. Food, Drink and Primary Production 4. Information and Communication Services 5. Modern Manufacturing 6. Traditional Manufacturing
Region in Ireland where firms are located	Categorical variable measuring firms' regional location: 1. Dublin (capital city) 2. Border Regions 3. Rest of Country
Domestic	Binary Variable = 1 if firm is Irish owned, otherwise 0.
Energy and Fuel Intensity (Natural Log)	Natural logarithm of a continuous variable measuring the Fuel and Energy intensity of each unit of gross value added (Yu et al. 2022). The variable measures the average during the latest 3 years before 2020.
Renewable Sources of Energy (Yes/No)	Binary variable = 1 if firms (a) Use fuel derived from biogas, bio-mass, and renewable waste; or (2) Have on-site renewable generation (e.g. heat pumps, solar panel, windmills), otherwise 0.
Importance of CARP (Yes/No)	Binary Variable = 1 if firms declare that having a CARP for their business is moderately or highly important, otherwise = 0.

Table 1 presents the variables used in our matching process. The variables in Table 1 capture key quantitative and qualitative underlying firm-level characteristics that have been shown in the literature to drive climate action in firms. More specifically, medium and large-sized firms have been shown to be more likely to develop CARPs in comparison to small-sized firms (Kouloukoui et al. 2021). Some studies have also outlined unique characteristics of micro firms (i.e. fewer than

[3] We repeated our analysis, by putting the firms declaring 'don't know' into the 'No' category. Table C2 in the Supplementary Material accompanying this paper presents the results of this additional analysis, which are very similar to the findings of our main analysis in Table 3.

10 employees) when investing in intangible resources, such as R&D (see, for example, Berends et al. 2014). To control for potential firm-size differences, we measure whether firms are micro-firms, small-sized firms between 10 and 19 employees, and small-sized firms with 20 to 49 employees. Additionally, we include a categorical variable measuring firms' industrial sectors as defined in the ABSEI survey, to control for sector-specific environmental and regulatory pressures which can affect firms' decisions to develop CARPs (Dewick et al. 2019). We also include a categorical variable measuring the region of Ireland where firms are located, to control for any potential region-specific heterogeneities. *A-priori*, we also expect domestic Irish firms and subsidiary firms of multinational corporations to differ in terms of their likelihood to develop CARPs, due to issues of financial resources and capabilities (Lenihan et al. 2024). We thus include a dummy variable measuring whether firms are of domestic ownership or not.

As discussed in Section 2.2, environmental resource intensive firms have specific incentives to develop CARPs. We thus include a variable measuring the average fuel and energy intensity of each unit of Gross Value Added. We also measure firms already using renewable sources of energy, and/or have developed systems to produce energy in-house, as such firms are likely to already have high levels of environmental knowledge. Finally, we measure if developing a CARP is important for firms' business activities, to control for qualitative differences across firms, in terms of the extent to which their business activities impact the natural environment.

Table 2 presents the variables considered in the second stage of our analysis, which form the main focus of our paper. We consider firm-level characteristics across five key areas, as discussed in Section 2.3. These are: (1) Firm-level performance; (2) Market forces; (3) R&D and digital capabilities; (4) Managerial resources; and (5) Linkages with Higher Education Institutions (HEIs).

Following standard practice, our main measure of firm performance is productivity, defined as average total sales per employee. We also include average profit growth, as firms' profits are an important source of internal funding. Finally, we include firms' average percentage of exports to total sales, to capture firms' abilities to compete in international markets. To measure R&D knowledge and capabilities, we include: (1) average R&D intensity, as a measure of absorptive capacity (Cohen and Levinthal 1990); (2) Whether firms carried out internal R&D, to capture if they benefited from learning by doing R&D in-house or not; (3) The average share of R&D employees to total number of employees, to account for the levels of R&D human capital resources; and (4) The average percentage of sales generated from innovations, to capture whether firms' innovations were successful in the market.

Digital technologies are vital for firm-level environmental efforts (Kren and Lawless 2023). We measure this with a dummy variable capturing whether firms already use and/or are in the process of using digital technologies, such as artificial intelligence and cloud computing. To measure market forces, we include two dummy variables measuring whether firms are public sector suppliers, and whether they compete in international markets (Shadrina et al. 2022). Firms' levels of managerial resources and variety of expertise are measured as the number of Directors on their Boards (Gallego-Álvarez and Rodriguez-Dominguez 2023). Finally, we measure managerial gender diversity with: (1) A variable measuring the percentage of female board members; and (2) A binary variable measuring whether firms' CEO or Chairperson are females (Saeed et al. 2022).

Table 2: Firms' characteristics used in the analysis

Performance Measures	**Definition**
Productivity (Continuous)	Average productivity (total sales per employee) during the most recent available 3 years since the year 2020 (in Thousand €).
Profit growth (%)	Percentage change between the two most recent years since the year 2020: ((year t - year t-1)/year t-1)*100.
Sales from exports (%)	Average percentage of sales from exports for the most recent available 3 years since the year 2020.
Knowledge / Capability Measures	**Definition**
R&D intensity (%)	Average total expenditure in R&D during the most recent available 3 years since the year 2020, divided by the total average sales during the same period. The variable is then multiplied by 100.
Internal R&D (Yes, No)	Binary variable = 1 if firms carried out internal R&D during the most recent available 3 years since the year 2020; otherwise = 0.
Share of R&D employees (%)	Average total number of R&D employees during the most recent available 3 years since the year 2020, divided by the total number of employees during the same period. The variable is then multiplied by 100.
Sales from innovation (%)	Average percentage of sales from new products or services during the most recent available 3 years since the year 2020. The variable is then multiplied by 100.
Digital readiness (Yes, No)	Binary variable =1 if firms use/have plans in place to use digital technologies (e.g. data analytics, artificial intelligence) in 2020, otherwise = 0.
Market Pressure Measures	**Definition**
Public sector supplier (Yes, No)	Binary variable = 1 if firms have supplied goods and services to Public Sector organisations during the previous 5 years before 2020, otherwise 0.
Export (Yes, No)	Binary variable = 1 if firms export, otherwise = 0.
Management Measures	**Definition**
Size of Board of Directors	Total number of persons on firms' Board of Directors in 2020.
Females on Board (%)	Number of females in 2020 who are Directors, divided by the total number of Directors on the Board in the same year. The variable is then multiplied by 100.
Female CEO/Chair (Yes, No)	Binary variable=1 if CEO or chair is female in 2020, otherwise = 0.
Linkages Measures	**Definition**
Links with HEIs (Yes, No)	Binary variable = 1 if firms already have established links with Higher Education Institutions (HEIs) to collaborate in environmental, digital and innovation activities, otherwise = 0.

4. Results

4.1 Descriptive Statistics and balance tests

Table A2 in the Supplementary Material accompanying this paper presents the descriptive statistics considering: (1) All firms in the sample; (2) Only firms that developed CARPs; and (3) Only firms that did not develop CARPs. The table shows that the percentage of firms developing and not developing CARPs is similar, in the context of small-sized firms with 10 to 19 employees, and 20 to 49 employees, respectively. However, a higher percentage of micro-firms can be observed in the group of firms not developing CARPs, in comparison to the group of firms developing CARPs (i.e. difference is approximately 8 percentage points). This aligns with *a-priori* expectations, whereby micro firms are the size category of firm most likely to face financial constraints (Berends et al. 2014). Moreover, firms that developed CARPs were more likely to use and/or produce renewable sources of energy and fuel, were more productive, in addition to having invested more in R&D and generated more sales from innovation. Finally, firms not developing CARPs were more likely to consider CARPs to be important for their business. This indicates, that whilst firms are increasingly aware of the importance of CARPs, they may be unable to commit organisational resources to develop such plans.

Table B1 and B2 in the Supplementary Material present the balance tests, following our PSM approach (1:3 and 1:1 respectively). The tables show that our matches were successful, as no statistically significant differences exist between firms that developed and did not develop CARPs, across the matching variables used.

4.2 Main findings

Table 3 presents our main findings, which are obtained from a 1:3 nearest neighbour matching approach. Table C1 in the Supplementary Material accompanying this paper presents the findings obtained from the 1:1 nearest neighbour matching approach. Section 4.3 presents and discusses additional analyses to test the robustness of our main findings. In all cases, our findings are robust across the different matching techniques and measures used.

From Table 3, we observe that firms that developed CARPs are more productive, as measured by average sales per employee ($p < 0.1$), and generate an average of 0.87 percentage point higher export share ($p < 0.01$) than firms not developing such plans. These findings are in line with our earlier discussion in Section 2.3, and with other studies that highlight high performing firms as being more likely to engage in environmental action, in comparison to less performing firms (Russo

and Fouts 1997; Rennings et al. 2006; Blanco et al. 2020). Based on our discussion in Section 2.3, a strong performance in the market can enable firms to develop CARPs through two main avenues. The first avenue is by enabling firms to develop internal funding to finance the development of CARPs. The second avenue is by relaxing the expectations that firms attach to their investments in intangible assets, in terms of returns to investment and timelines. Our results support these avenues.

Table 3: Characteristics of firms developing Climate Action Response Plans (CARPs)

	Developed CARP	Did not develop CARP	Difference	Standard Error	T-Stat
Performance measures					
Productivity (Continuous)	259.645	216.166	43.478*	22.463	1.930
Profit growth (%)	-2.050	-10.544	8.493	8.944	0.950
Sales from exports (%)	41.251	40.378	0.873***	0.211	2.330
R&D and Innovation Measures					
R&D Intensity (Continuous)	16.967	12.900	4.067***	1.193	3.400
Internal R&D (Yes, No)	0.804	0.689	0.114***	0.033	3.410
Share of R&D employees (%)	13.536	11.356	2.179**	0.921	2.360
Sales from innovation (%)	13.586	9.915	3.671**	1.559	2.350
Digital readiness (Yes, No)	0.497	0.346	0.150***	0.038	3.990
Market Pressure Measures					
Public sector supplier (Yes, No)	0.396	0.356	0.040	0.037	1.070
Export (Yes, No)	0.907	0.851	0.056**	0.025	2.170
Managerial Resources					
Size of Board of Directors (Continuous)	4.155	3.820	0.335	0.260	1.290
Females on Board (%)	0.053	0.047	0.0053	0.019	0.280
Female CEO/Chair (Yes, No)	0.097	0.092	0.005**	0.002	2.200
External Links					
Established links with HEIs	0.276	0.208	0.067**	0.031	2.13

Notes: *p < 0.1; **p < 0.05; ***p < 0.01. Estimation results based on a 1:3 nearest neighbour matching approach. The coefficients in 'Difference' relate to the difference between firms that developed CARPs and firms that did not develop CARPs. See Table 2 for a detailed description of all variables. Table B1 in the Supplementary Material accompanying this paper presents the balance properties, showing that firms that did and did not develop CARPs are balanced across key underlying characteristics.

Firms that developed CARPs also outperform firms that did not develop such plans, across all measures of R&D an innovation considered. On average, firms that developed CARPs have higher levels of R&D intensity ($p < 0.01$), are more likely to carry out internal R&D ($p < 0.01$), have a higher share of R&D employees ($p < 0.01$), and generate a higher percentage of sales from innovation, at around 3.7 percentage points on average ($p < 0.05$). The importance of R&D and innovation capabilities has been shown to be relevant for climate related activities, such as for example, circular economy activities (Garrido-Prada et al. 2021) and environmental innovation (Ghisetti et al. 2021). These findings further highlight the central role that firms' capacities to learn

and apply new knowledge play in driving their responses to climate change. A similar finding is observed in the context of digital technologies, as digital ready firms are more likely to develop CARPs, than those firms that are not digital ready ($p < 0.01$). This highlights the interlinkages between the digital and environmental transition in firms (Chatzistamoulou 2023).

In the context of market pressures, we do not find that public sector suppliers are more likely to develop CARPs. This finding does not concur with previous studies outlining public procurement to incentivise firms to design and implement environmentally friendly innovations, strategies and business practices (e.g. Shadrina et al. 2022). However, we find that firms that compete in international markets are slightly more likely to develop CARPs, at around 0.06 percentage points ($p < 0.05$). Our findings therefore suggest that 'market pull' forces mainly take place as firms engage with international consumers and clients (Horbach et al. 2012).

In terms of managerial resources (such as Board of Directors size), firms developing CARPs do not have more managerial resources than firms not developing such plans. We only find that the former are slightly more likely to have a female CEO and/or Chairperson, at around 0.5 percentage points ($p < 0.05$). Our findings thus do not support that managerial resources, at least in the way we were able to measure them, are an important determining factor for firms when developing CARPs. Finally, we find that firms that developed CARPS are more likely to collaborate with Higher Education Institutions (HEIs) than firms not developing such plans (the difference is 6.7 percentage points, $p < 0.05$). This supports the argument that HEIs could serve as an important entry point for accessing and developing new climate change related knowledge (Garrido-Prada et al. 2021).

4.3 Additional analysis

Tables D1 and D2 in the Supplementary Material accompanying this paper present the findings obtained when focussing our analysis on (1) Small-sized firms only (fewer than 50 employees); and (2) Larger-sized firms only (50 or more employees). The results are very similar to those presented in Table 3, indicating that our main findings hold for both small and medium to large firms. There are however, two important issues to note. The variables *Export* and *Female CEO/Chair* are only positive and significant in the context of small-sized firms. This may be explained by the fact that most larger-sized firms engage in the export markets (not the case for small-sized firms). Previous research has also shown that CEOs in small-sized firms can play an important role in determining the activities that such firms engage in (e.g. Berends et al. 2014).

As noted earlier in Section 3.3, a key first step in implementing CARPs is firms measuring their CO_2 emissions. Therefore, we extend our analysis to account for the extent to which firms are implementing CARPs (as opposed to simply developing CARPs), by focusing on whether they measure their CO_2 emissions. Table E1 in the Supplementary Material presents the results of this analysis, which mostly mirror the findings from Table 3 and Table C1. However, there are some important differences. For example, while our measures of exports are positive and significant in Table 3 and Table C1, this is no longer the case in Table E1. The same occurs for the measures of R&D employees, and the percentage of sales derived from innovation. We interpret these differences to suggest that, the extent to which firms implement CARPs mainly relates to *whether* (as opposed to *what extent*) firms operate in international markets, invest in R&D and innovation, and/or generate sales from innovation.

5. Discussion and conclusion

Firm-level Climate Action Response Plans (CARPs) can be critical for firms adopting holistic responses to climate change. Researchers and policymakers alike have stressed the vital importance of encouraging firms to develop and implement CARPs. However, our understanding of the extent to which firms are developing CARPs, and the characteristics of firms leading these efforts, remains scarce. Our paper addresses this gap in existing knowledge, by providing the first in-depth empirical examination of the characteristics that distinguish firms that develop (do not develop) CARPs. We achieve this by building on a unique and rich database with information on firms in Ireland, and using a propensity score matching approach to address issues of endogeneity and reverse causality. Prior research has been hampered by the lack of detailed data, an issue which we overcome in this paper. To the best of our knowledge, this is the first paper seeking to understand the characteristics of firms planning for a more sustainable future, by means of developing CARPs.

We find that firms developing CARPs tend to have a strong market performance, are highly R&D and innovation active, and already benefit from digital technologies in their existing business activities. These findings are robust across several model specifications, and measures of CARPs used (e.g. whether firms developed CARPs or whether they measured CO_2 emissions). We interpret these results by conceptualising CARPs as a form of intangible asset, similar to firms' investments in R&D and innovation. Viewed this way, firms need to have good market performance to generate internal financial resources to finance the development of CARPs. Moreover, the development of CARPs likely necessitates firms to generate and absorb new knowledge. Having R&D and innovative capabilities and absorptive capacity in-house is thus vital, as firms can leverage this knowledge to plan their climate change mitigation and adaptation activities. In this context, already

using digital technologies such as artificial intelligence, cloud computing, and other similar technologies that improve and help monitor firms' operations, can enable and encourage climate action in firms (Chatzistamoulou 2023).

Our findings also suggest that firms developing CARPs tend to operate in international markets, as measured by whether they export or not. Again, this supports that firms developing CARPs are highly competitive, as demonstrated by the fact that they already compete in international markets. In addition, being present in international markets may provide additional incentives for firms to develop CARPs. As countries implement stronger policies to mitigate climate change, customers may demonstrate an increased awareness towards the climate impacts of the products and services they consume and use. This should spur exporting firms to take action towards better climate performance, in order to respond to international market trends and consumer preferences (see Horbach and Rammer 2025). Moreover, we do not find that the development of CARPs is associated with firms being public sector suppliers. We interpret this finding as evidence of firms in Ireland primarily responding to consumer preferences and trends in export markets, as opposed to responding to the requirement of public procurement guidelines and processes. This highlights the importance of consumers as the key drivers of market pull effects, as opposed to public procurement (Shadrina et al. 2022).

Having provided new empirical evidence regarding the characteristics of firms that develop (do not develop) CARPs, we now turn to consider the potential role for policy and its associated interventions/instruments. The discussion that follows can be useful for any eventual design and implementation of policy interventions, by acknowledging the importance of firm heterogeneities, when it comes to nudging firms to develop CARPs. The flavour of what follows below is that policy intervention will provide firms with assistance to stimulate their own activities for developing CARPs. Overtime and once firms start to realise the benefits that derive from CARPs development, they themselves should then reduce their dependency on policy interventions for CARPs development. Yet, as outlined by Lenihan et al. (2019) "Policy has a role to play in terms of helping firms to identify and improve the capacity they already have" (p. 103791).

A key insight of our study is that developing CARPs can require firms to have sufficient levels of financial and knowledge resources. Clearly, a potential role for policy exists in terms of facilitating firms to gain access to such financial and knowledge resources where associated market/systemic failures exist. However, simply encouraging firms to develop CARPs may be unlikely to yield satisfactory results, without also supporting firms to become more productive, and to develop complementary knowledge. This provides support for studies highlighting that enabling and

encouraging firms to improve their environmental performance to fight against climate change, requires a combination of different complementary policy instruments (Wilts and O'Brien 2019). In the context of CARPs, such policy instruments may usefully target improving market and innovative performance in firms, while also enabling a supportive environment for firms benefiting from the increasing prominence of digital technologies. Relatedly, public investments in the generation of local environmental knowledge, by means of supporting research in Higher Education Institutions (HEIs) focused on energy and the environment, can be important for making much needed relevant knowledge available to firms. The strong connection between developing CARPs and a firm's innovative capabilities also implies that many firms with limited resources to develop and implement new technology and new products, are not taking systematic action to address climate change issues. In order to motivate these firms to take action, environmental policy may adopt approaches from innovation policy to encourage firms to develop innovative capabilities, including consultancy schemes (e.g. strategy reviews) and human capital-oriented programmes (e.g. schemes to train personnel in climate change awareness and management).

Another key insight of our paper relates to the importance of consumers, at the time of encouraging environmental efforts by firms. This is crucial, as firms are increasingly highlighted as failing to contribute to addressing the global grand challenge of climate change (Le Ravalec et al. 2022; Johnson et al. 2023). Based on our findings, however, firms' slow responses to climate change may reflect deeper challenges at a societal level, to effectively respond to climate change. Firms may not find it necessary to engage in CARPs, when consumers do not account for this issue in their demand preferences (Vollebergh 2023). This suggests that supply side policy efforts to encourage firms to plan for a more sustainable future, by means of CARPs, may be accompanied by policy interventions focused on driving more climate friendly consumer behaviour (Wilts and O'Brien 2019). It should also be acknowledged that policymakers, with the objective of encouraging firms to develop CARPs, can garner useful lessons (good and bad) from the cannon of literature that already exists on policy interventions pertaining to R&D and innovation. This is because we conceptualise a firm developing a CARP, as similar to investing in intangible assets such as R&D and innovation. This means that having established the specific target firm population as we do in this paper, policymakers can hit the ground running, often without the need to reinvent the wheel when it comes to designing and implementing policy interventions concerned with kick-starting and nudging firms to develop CARPs.

It would be remiss to ignore the potential managerial and practice (at firm level) implications of our findings. As such, they suggest the need for management (or often in the case of micro and smaller firms' owner managers) to foster an environment where firms (and moreover, the

employees therein) intensify their climate change mitigation and adaptation efforts. CARPs are pivotal in this regard. Even with a vast range of policy interventions, CARPs will never be developed and improved (and the associated benefits accrued) without corporate commitment to climate change action. Introducing a CARP is after all, a key management decision by firms. What is noteworthy, is that our findings do not suggest that firms developing CARPs had more managerial resources than firms not developing such plans. We also only find that the former were slightly more likely to have a female CEO and/or Chairperson. To leverage the full potential of CARPs, they are best integrated into a firm's other strategic actions, including marketing, new product development, internationalisation and investments. It is highly probable that firms with better developed management capabilities and resources, will find it easier to reap the potential of CARPs, and hence, will be more likely to develop them.

Our analysis is not free from limitations, which can guide future research on this topic. Firstly, our rich and detailed firm-level data are a strength of our paper, but only comprise firms in a specific country context (Ireland). Future studies may usefully replicate our analysis in multiple country contexts. Secondly, we assume a focus on both climate change mitigation and adaptation in CARPs, given the holistic nature of these plans. However, our data do not permit ascertaining whether this is indeed the case. Future studies may delve deeper into the activities included in CARPs. Finally, we can only ascertain whether firms have developed CARPs or not but cannot ascertain a precise timeline regarding such development. It is important to note that our focus on CARPs does not extend to the firm-level impacts, in terms of environmental performance, that emanate from developing CARPs. This can serve as a basis for future research. Despite these limitations, our study offers novel and timely insights for addressing a key gap in existing knowledge, and potentially informing future policy efforts to encourage firms to develop CARPs.

References

Albitar, K., Al-Shaer, H., and Liu, Y.S. (2023) 'Corporate commitment to climate change: The effect of eco-innovation and climate governance', *Research Policy,* 52(2), 104697, DOI: https://doi.org/10.1016/j.respol.2022.104697.

Aldieri, L., Makkonen, T., and Vinci, C.P. (2022) 'Do research and development and environmental knowledge spillovers facilitate meeting sustainable development goals for resource efficiency?', *Resources Policy*, 76, 102603, DOI: https://doi.org/10.1016/j.resourpol.2022.102603.

Amar, J., Demaria, S., and Rigot, S. (2023) 'What are the drivers of corporates' climate transparency? Evidence from the S&P 1200 index', *Ecological Economics*, 213, 107945, DOI: https://doi.org/10.1016/j.ecolecon.2023.107945.

Anderson, B., Cammeraat, E., Dechezleprêtre, A., Dressler, L., Gonne, N., Lalanne, G., Martins Guilhoto, J., and Theodoropoulos, K. (2023) 'Designing policy packages for a climate-neutral industry: A case

study from the Netherlands', *Ecological Economics*, 205, 107720, DOI: https://doi.org/10.1016/j.ecolecon.2022.107720.

Austin, P.C. (2011) 'Optimal caliper widths for propensity-score matching when estimating differences in means and differences in proportions in observational studies', *Pharmaceutical Statistic*s, 10(2), 150–161, DOI: https://doi.org/10.1002/pst.433.

Backman, C.A., Verbeke, A., and Schulz, R.A. (2015) 'The drivers of corporate climate change strategies and public policy: A new resource-based view perspective', *Business & Society*, 56(4), 545–575, DOI: https://doi.org/10.1177/0007650315578450.

Ben-Amar, W., Gomes, M., Khursheed, H., and Marsat, S. (2022) 'Climate change exposure and internal carbon pricing adoption', *Business Strategy and the Environment*, 31(7), 2854–2870, DOI: https://doi.org/10.1002/bse.3051.

Blanco, C.C., Caro, F., and Corbett, C.J. (2020) 'Do carbon abatement opportunities become less profitable over time? A global firm-level perspective using CDP data', *Energy Policy*, 138, 111252, DOI: https://doi.org/10.1016/j.enpol.2020.111252.

Berends, H., Jelinek, M., Reymen, I., and Stultiëns, R. (2014). 'Product Innovation Processes in Small Firms: Combining Entrepreneurial Effectuation and Managerial Causation', *Journal of Product Innovation Management*, 31(3), 616–635, DOI: https://doi.org/10.1111/jpim.12117.

Bose, S., Lim, E.K., Minnick, K., and Shams, S. (2023) 'Do foreign institutional investors influence corporate climate change disclosure quality? International evidence', *Corporate Governance: An International Review*, 1–26. DOI: https://doi.org/10.1111/corg.12535

Caloffi, A., Freo, M., Ghinoi, S., Mariani, M., and Rossi, F. (2022) 'Assessing the effects of a deliberate policy mix: The case of technology and innovation advisory services and innovation vouchers', *Research Policy*, 51(6), 104535, DOI: https://doi.org/10.1016/j.respol.2022.104535.

Carbon Disclosure Project (CDP) (2024) 'CDP Climate Change Scoring Essential Criteria 2024', Available at: https://cdn.cdp.net/cdp-production/comfy/cms/files/files/000/009/177/original/CDP_Climate_Change_Scoring_Essential_Criteria_2024.pdf.

Chatzistamoulou, N. (2023) 'Is digital transformation the Deus ex Machina towards sustainability transition of the European SMEs?', *Ecological Economics*, 206, 107739, DOI: https://doi.org/10.1016/j.ecolecon.2023.107739.

Chatzistamoulou, N., and Tyllianakis, E. (2022) 'Green growth & sustainability transition through information. Are the greener better informed? Evidence from European SMEs', *Journal of Environmental Management*, 306, 114457, DOI: https://doi.org/10.1016/j.jenvman.2022.114457.

Coen, D., Herman, K., and Pegram, T. (2022) 'Are corporate climate efforts genuine? An empirical analysis of the climate "talk–walk" hypothesis', *Business Strategy and the Environment*, 31(7), 2767–3688, DOI: https://doi.org/10.1002/bse.3063.

Cohen, W.M. and Levinthal, D.A. (1990) 'Absorptive Capacity: A New Perspective on Learning and Innovation', *Administrative Science Quarterly*, 35(1), 128–152, DOI: http://www.jstor.org/stable/2393553.

De Abreu, M.C.S., Webb, K., Araújo, F.S.M., and Cavalcante, J.P.L. (2021) 'From "business as usual" to tackling climate change: Exploring factors affecting low-carbon decision-making in the canadian oil and gas sector', *Energy Policy*, 148, 111932, DOI: https://doi.org/10.1016/j.enpol.2020.111932.

Department of Enterprise, Trade and Employment (DETE) (2020) Annual Business Survey of Economic Impact (ABSEI) 2020. Available at: https://enterprise.gov.ie/en/publications/publication-files/annual-business-survey-of-economic-impact-2020-report.pdf [Accessed on 19-9-2022].

Dewick, P., Maytorena-Sanchez, E., and Winch, G. (2019) 'Regulation and regenerative eco-innovation: the case of extracted materials in the UK', *Ecological Economics*, 160, 38–51, DOI: https://doi.org/10.1016/j.ecolecon.2019.01.034.

Fremstad, A., and Paul, M. (2022) 'Neoliberalism and climate change: How the free-market myth has prevented climate action', *Ecological Economics*, 197, 107353, DOI: https://doi.org/10.1016/j.ecolecon.2022.107353.

Gallego-Álvarez, I., and Rodriguez-Dominguez, L. (2023) 'Board of directors and environmental practices: the effect of board experience, culture, and tenure', *Environment, Development and Sustainability*, DOI: https://doi.org/10.1007/s10668-023-03937-z.

Gans, W. and Hintermann, B. (2013) 'Market Effects of Voluntary Climate Action by Firms: Evidence from the Chicago Climate Exchange', *Environmental and Resource Economics*, 55(2), 291–308, DOI: https://doi.org/10.1007/s10640-012-9626-7.

Garrido-Prada, P., Lenihan, H., Doran, J., Rammer, C., and Perez-Alaniz, M. (2021) 'Driving the circular economy through public environmental and energy R&D: Evidence from SMEs in the European Union', *Ecological Economics*, 182, 106884, DOI: https://doi.org/10.1016/j.ecolecon.2020.106884.

Ghisetti, C., Montresor, S., and Vezzani, A. (2021) 'Design and environmental technologies: Does "green-matching" actually help?', *Research Policy*, 50(5), 104208, DOI: https://doi.org/10.1016/j.respol.2021.104208.

Hampton, S., Blundel, R., Eadson, W., Northall, P., and Sugar, K. (2023) 'Crisis and opportunity: Transforming climate governance for SMEs', *Global Environmental Change*, 82, 102707, DOI: https://doi.org/10.1016/j.gloenvcha.2023.102707.

Horbach, J., and Rammer, C. (2025) 'Climate change affectedness and innovation in firms', *Research Policy*, 54(1), 105122, DOI: https://doi.org/10.1016/j.respol.2024.105122.

Horbach, J., Rammer, C., and Rennings, K. (2012) 'Determinants of eco-innovations by type of environmental impact — The role of regulatory push/pull, technology push and market pull', *Ecological Economics*, 78, 112–122, DOI: https://doi.org/10.1016/j.ecolecon.2012.04.005.

Johnson, M.P., Rötzel, T.S., and Frank, B. (2023) 'Beyond conventional corporate responses to climate change towards deep decarbonization: a systematic literature review', *Management Review Quarterly,* 73(2), 921–954, DOI: https://doi.org/10.1007/s11301-023-00318-8.

Karim, A., Albitar, K., and Elmarzouky, M. (2021) 'A novel measure of corporate carbon emission disclosure, the effect of capital expenditures and corporate governance', *Journal of Environmental Management*, 290, 112581, DOI: https://doi.org/10.1016/j.jenvman.2021.112581.

Klingebiel, R., and Rammer, C. (2020) 'Optionality and Selectiveness in Innovation', *Academy of Management Discoveries*, 7(3), 328–342, DOI: https://doi.org/10.5465/amd.2018.0024.

Kouloukoui, D., de Marcellis-Warin, N., Armellini, F., Warin, T., and Torres, E.A. (2021) 'Factors influencing the perception of exposure to climate risks: Evidence from the world's largest carbon-intensive industries', *Journal of Cleaner Production*, 306, 127160, DOI: https://doi.org/10.1016/j.jclepro.2021.127160.

Krieger, B., and Zipperer, V. (2022) 'Does green public procurement trigger environmental innovations?', *Research Policy*, 51(6), 104516, DOI: https://doi.org/10.1016/j.respol.2022.104516.

Kren, J., and Lawless, M. (2023) 'Firm-level attitudes and actions to the "Twin Transition" challenges of digitalisation and climate change', ESRI Working Paper 742, Dublin: ESRI, Available at: https://www.esri.ie/publications/firm-level-attitudes-and-actions-to-the-twin-transition-challenges-of-digitalisation.

Lainé, M. (2023) 'How to reconcile actual climate change mitigation with prosperity? A proposal', *Ecological Economics,* 204, DOI: https://doi.org/10.1016/j.ecolecon.2022.107679.

Le Ravalec, M., Rambaud, A., and Blum, V. (2022) 'Taking climate change seriously: Time to credibly communicate on corporate climate performance', *Ecological Economics*, 200, 107542, DOI: https://doi.org/10.1016/j.ecolecon.2022.107542.

Lenihan, H., McGuirk, H., and Murphy, K. R (2019) 'Driving innovation: public policy and human capital', *Research Policy* 48 (9), 103791, DOI: https://doi.org/10.1016/j.respol.2019.04.015.

Lenihan, H., Mulligan, K., Doran, J. Rammer, C., and Ipinnaiye, O. (2024) 'R&D grants and R&D tax credits to foreign-owned subsidiaries: Does supporting multinational enterprises' R&D pay off in terms of firm performance improvements for the host economy?', *Journal of Technology Transfer* 49(2), 740–781, DOI: https://doi.org/10.1007/s10961-023-09995-9.

Littlewood, D., Decelis, R., Hillenbrand, C., and Holt, D. (2018) 'Examining the drivers and outcomes of corporate commitment to climate change action in European high emitting industry', *Business Strategy and the Environment,* 27(8), 1437–1449, DOI: https://doi.org/10.1002/bse.2194.

Montresor, S., and Vezzani, A. (2021) 'Financial Constraints to Investing in Intangibles: Do Innovative and Non-Innovative Firms Differ?', *Journal of Technology Transfer*, 47, 1–32, DOI: https://doi.org/10.1007/s10961-020-09842-1.

Negri, M.; Neri, A.; Cagno, E.; Monfardini, G. (2021) 'Circular Economy Performance Measurement in Manufacturing Firms: A Systematic Literature Review with Insights for Small and Medium Enterprises and

New Adopters', *Sustainability*, 13(16), 9049, DOI: https://doi.org/10.3390/su13169049.

OECD (2019) 'SME and Entrepreneurship Policy in Ireland, OECD Studies on SMEs and Entrepreneurship', Paris: OECD Publishing, Available at: https://doi.org/10.1787/e726f46d-en.

Perez-Alaniz, M., Lenihan, H., Doran, J., and Hewitt-Dundas, N. (2023) 'Financial resources for research and innovation in small and larger firms: Is it a case of the more you have, the more you do?', *Industry and Innovation*, 30(2), 189–232, DOI: https://doi.org/10.1080/13662716.2022.2036597.

Rennings, K. (2000) 'Redefining innovation — eco-innovation research and the contribution from ecological economics', *Ecological Economics*, 32(2), 319–332, DOI: https://doi.org/10.1016/S0921-8009(99)00112-3.

Rennings, K., Ziegler, A., Ankele, K., and Hoffmann, E. (2006) 'The influence of different characteristics of the EU environmental management and auditing scheme on technical environmental innovations and economic performance', *Ecological Economics*, 57(1), 45–59, DOI: https://doi.org/10.1016/j.ecolecon.2005.03.013.

Russo, M. V and Fouts, P.A. (1997) 'A Resource-Based Perspective on Corporate Environmental Performance and Profitability', *The Academy of Management Journal*, 40(3), 534–559, DOI: http://www.jstor.org/stable/257052.

Saeed, A., Riaz, H., Liedong, T.A., and Rajwani, T. (2022) 'The impact of TMT gender diversity on corporate environmental strategy in emerging economies', *Journal of Business Research*, 141, 536–551, DOI: https://doi.org/10.1016/j.jbusres.2021.11.057.

Schöller, V., and Ulmer, C. (2023) 'Can monetized carbon information increase pro-environmental behavior? Experimental evidence', *Ecological Economics*, 206, 107759, DOI: https://doi.org/10.1016/j.ecolecon.2023.107759.

Shadrina, E. V, Vinogradov, D.V., and Kashin, D. V (2022) 'Implicit incentives in green public procurement: Good intentions versus rigid regulations', *Ecological Economics*, 198, 107458, DOI: https://doi.org/10.1016/j.ecolecon.2022.107458.

Vanino, E., Roper, S., and Becker, B. (2019) 'Knowledge to money: Assessing the business performance effects of publicly-funded R&D grants', *Research Policy*, 48(7), 1714–1737, DOI: https://doi.org/10.1016/J.RESPOL.2019.04.001.

Vollebergh, H. (2023) 'Evaluating policy packages for a low-carbon transition – Principles and applications', *Ecological Economics*, 212, 107919, DOI: https://doi.org/10.1016/j.ecolecon.2023.107919.

Walenta, J. (2020) 'Climate risk assessments and science-based targets: A review of emerging private sector climate action tools', *WIREs Climate Change*, 11(2), e628, DOI: https://doi.org/10.1002/wcc.628.

Westman, L., Moores, E., and Burch, S. L. (2021) 'Bridging the governance divide: The role of SMEs in urban sustainability interventions', *Cities*, 108, 102944, DOI: https://doi.org/10.1016/j.cities.2020.102944.

Wilts, H. and O'Brien, M. (2019) 'A Policy Mix for Resource Efficiency in the EU: Key Instruments, Challenges and Research Needs', *Ecological Economics*, 155, 59–69, DOI: https://doi.org/10.1016/j.ecolecon.2018.05.004.

Yu, S., Liu, J., Hu, X., and Tian, P. (2022) 'Does development of renewable energy reduce energy intensity? Evidence from 82 countries', *Technological Forecasting and Social Change*, 174, 121254, DOI: https://doi.org/10.1016/j.techfore.2021.121254.

Acknowledgements

This publication has emanated from research conducted with the financial support of Science Foundation Ireland under Grant number 17/SPR/5328. For the purpose of Open Access, the authors have applied a CC BY public copyright license to any Author Accepted Manuscript version arising from this submission. Results are based on analysis of strictly controlled Research Microdata Files provided by the Central Statistics Office (CSO). The CSO does not take any responsibility for the views expressed or the outputs generated from this research. We gratefully acknowledge the Central Statistics Office and the Department of Enterprise, Trade and Employment for providing data for this research. The authors are grateful for feedback obtained on earlier versions of this paper presented at the *Visiting and Seminar Programme* of the University of Barcelona's Chair of Energy Sustainability (March-14, 2024), *The Irish Economic Association Annual Conference 2024* in Galway, Ireland (May 8-10, 2024), the *XXVI Applied Economics Meeting* in Santander, Spain (June 6-7, 2024), and the *2024 DRUID Annual Conference* in Nice, France (June 13-15, 2024).

Supplementary Material

Table A1: Results of Probit estimation to obtain firms' Propensity Scores

Independent Variables	Developed CARP (1 = Yes)	Measure CO_2 (1 = Yes)
Domestic	-0.914***	-0.937***
	(0.323)	(0.157)
Micro Firm < 10 employees	-0.411***	-0.421***
	(0.042)	(0.086)
Small Firm 10-19 employees	-0.133	-0.342***
	(0.169)	(0.172)
Small Firm 20-49 employees	-0.085	-0.132
	(0.091)	(0.164)
Sector 1: Business Financial and Other Services	-0.159***	0.417***
	(0.034)	(0.050)
Sector 2: Energy, Water, Waste and Construction	0.066*	0.211***
	(0.036)	(0.064)
Sector 3: Food, Drink and Primary Production	0.344***	0.291***
	(0.028)	(0.047)
Sector 4: Information and Communication Services	-0.145**	0.290***
	(0.046)	(0.064)
Sector 5: Modern Manufacturing	0.039**	-0.026
	(0.015)	(0.021)
Region. Border	-0.120**	0.073
	(0.053)	(0.179)
Region. Rest of South and East	-0.131	0.054
	(0.092)	(0176)
Energy and Fuel Intensity (Natural Log)	0.125***	0.012
	(0.025)	(0.050)
Generation and use of Renewable Sources of Energy	0.498***	0.260***
	(0.079)	(0.059)
Importance of Climate Action Response Plan (CARP)	0.616***	0.294***
	(0.299)	(0.048)
Constant	-0.991***	-0.717*
	(0.203)	(0.391)
Observations	1,959	1,961
Log likelihood	-819.439	-576.491
R^2	0.186	0.165

Note: * p < 0.1; ** p < 0.05; *** p < 0.01. Robust standard errors in parentheses. This table presents the result of probit models, which estimate firms' probabilities of developing Climate Action Response Plans-CARPs (Column 1) and Measuring CO_2 (Column 2). Coefficients are log likelihoods. Base category for variable Sector is Traditional Manufacturing. Base variable for region is Dublin (capital city).

Table A2 Descriptive Statistics

	Total Sample				Firms Developed CARP				Firms Did Not Develop CARP			
Variables	Mean	Standard Dev.	Min	Max	Mean	Standard Dev.	Min	Max	Mean	Standard Dev.	Min	Max
Stage 1 (Matching Variables)												
Micro Firm < 10 employees	0.139	0.346	0	1	0.110	0.314	0	1	0.190	0.392	0	1
Small Firm 10-19 employees	0.119	0.299	0	1	0.110	0.314	0	1	0.114	0.318	0	1
Small Firm 20-49 employees	0.175	0.380	0	1	0.186	0.390	0	1	0.190	0.393	0	1
Domestic (Yes/No)	0.941	0.413	0	1	0.965	0.183	0	1	0.992	0.089	0	1
Energy and Fuel Intensity (Natural Log)	4.528	2.021	-4.960	15.037	4.124	1.840	-0.706	12.361	4.366	1.785	-4.269	11.459
Renewable Sources of Energy (Yes/No)	0.096	0.295	0	1	0.247	0.432	0	1	0.095	0.294	0	1
Importance of CARP (Yes/No)	0.173	0.083	0	1	0.240	0.092	0	1	0.569	0.072	0	1
Stage 2 (Main Analysis)												
Productivity (Continuous)	208.31	277.939	0	3988.4	264.03	357.398	0	3988.4	192.33	242.306	0	3625.3
Profit growth (%)	-10.976	115.937	-189	220	-0.876	115.161	-120	200	-15.100	116.152	-235	220
Sales from export (%)	42.425	36.488	0	100	42.199	34.461	0	100	43.125	36.998	0	100
R&D Intensity (Continuous)	16.243	94.642	0	2625	16.421	135.313	0	2625	17.298	84.921	0	2111.1
Internal R&D (Yes, No)	0.723	0.447	0	1	0.808	0.394	0	1	0.710	0.453	0	1
Share of R&D employees (%)	15.516	34.194	0	100	13.174	21.759	0	100	16.650	37.621	0	100
Sales from innovation (%)	11.129	19.800	0	100	13.272	21.266	0	100	10.731	19.466	0	100
Digital readiness (Yes, No)	0.397	0.489	0	1	0.497	0.500	0	1	0.372	0.483	0	1
Public sector supplier (Yes, No)	0.415	0.492	0	1	0.388	0.487	0	1	0.426	0.494	0	1
Export (Yes, No)	0.872	0.333	0	1	0.910	-0.286	0	1	0.871	0.334	0	1
Size of Board of Directors (Continuous)	3.764	2.745	0	60	4.177	2.840	0	23	3.632	2.720	0	60
Females on Board (%)	0.441	0.178	0	5	0.054	0.159	0	1.98	0.041	0.191	0	5
Female CEO/Chair (Yes, No)	0.082	0.275	0	1	0.097	0.296	0	1	0.077	0.266	0	1
Established links with HEIs (Yes/No)	0.192	0.394	0	1	0.281	0.450	0	1	0.170	0.375	0	1
Number of Firms	**1,959**				**460**				**1,499**			

Table B1: Sample Balance Properties 1:3 Nearest neighbour Matching

Key matching variables	Developed CARP	Did not develop CARP	Difference	T-Stat	P-Value
Domestic	0.979	0.979	0.000	0.08	0.934
Small Firm < 10 employees	0.083	0.079	0.004	0.29	0.771
Small Firm 10-19 employees	0.106	0.112	-0.006	-0.32	0.751
Small Firm 20-49 employees	0.210	0.225	-0.015	-0.60	0.547
Sector: Business Financial and Other Services	0.060	0.076	-0.016	-0.93	0.351
Sector: Energy, Water, Waste and Construction	0.228	0.249	-0.021	-0.72	0.472
Sector: Food, Drink and Primary Production	0.187	0.197	-0.010	-0.33	0.742
Sector: Information and Communication Services	0.092	0.087	0.005	0.25	0.805
Sector. Modern Manufacturing	0.250	0.239	0.011	0.36	0.722
Region. Border	0.348	0.320	0.028	0.82	0.410
Region. Rest of South and East	0.423	0.398	0.025	0.72	0.472
Energy and Fuel Intensity (Natural Log)	4.141	4.001	0.140	1.07	0.283
Generation and use of Renewable Sources of Energy	0.240	0.221	0.019	0.64	0.520
Importance Climate Action Response Plan (CARP)	0.237	0.236	0.001	0.01	0.990

Ps-R^2	LR-Chi2	p>Chi2	Mean Bias	Med Bias	Rubin's B	Rubins' R	CARP= Yes	CARP= No
0.006	6.891	0.865	3.9	3.9	17.4	0.88	412	1,499

Note: The balancing properties presented in this table are obtained with a 1:3 matching approach. The bottom panel presents the diagnostic tests developed by Leuven and Sianesi (2018), by implementing the pstest command in STATA. Ps-R2 is the pseudo R2 from the probit estimation and the corresponding Chi2 statistic and p-value of the likelihood-ratio test of joint significance of covariates. In addition, the panel includes the mean and median bias as summary indicators of the distribution of bias across the samples. The Rubin's B score represents the standardised difference of means of a linear index of the propensity score in treated and control firms. The Rubin's R is the ratio of treated to matched non-treated variances of the propensity score index. Values below 25 for Rubin's B, and between 0.5 and 2 for Rubin's R, are usually accepted as indicating a sufficiently balanced sample, as per the guidelines of Rosenbaum and Rubin (1985).

Table B2: Sample Balance Properties 1:1 Nearest neighbour Matching

Key matching variables	Developed CARP	Did not develop CARP	Difference	T-Stat	P-Value
Domestic	0.979	0.969	0.010	0.910	0.366
Small Firm < 10 employees	0.926	0.103	0.823	-0.480	0.634
Small Firm 10-19 employees	0.103	0.092	0.011	0.480	0.634
Small Firm 20-49 employees	0.203	0.226	-0.023	-0.780	0.438
Sector. Business Financial and Other Services	0.601	0.602	-0.001	-0.150	0.883
Sector. Energy, Water, Waste and Construction	0.228	0.220	0.008	0.250	0.799
Sector. Food, Drink and Primary Production	0.187	0.203	-0.016	-0.540	0.593
Sector. Information and Communication Services	0.092	0.090	0.002	0.120	0.902
Sector. Modern Manufacturing	0.250	0.270	-0.02	-0.640	0.519
Region. Border	0.348	0.338	0.01	0.300	0.766
Region. Rest of South and East	0.423	0.413	0.01	0.290	0.774
Energy and Fuel Intensity (Natural Log)	4.141	4.045	0.096	0.730	0.468
Generation and use of Renewable Sources of Energy	0.240	0.180	0.060	2.090	0.037
Importance Climate Action Response Plan (CARP)	2.360	2.273	0.087	1.360	0.174

Ps-R^2	LR-Chi2	p>Chi2	Mean Bias	Med Bias	Rubin's B	Rubins' R	CARP= Yes	CARP= No
0.008	9.35	0.0673	4.8	3.1	18.6	0.88	412	1,547

Note: The balancing properties presented in this table are obtained with a 1:1 matching approach. The bottom panel presents the diagnostic tests developed by Leuven and Sianesi (2018), by implementing the pstest command in STATA. Ps-R2 is the pseudo R2 from the probit estimation and the corresponding Chi2 statistic and p-value of the likelihood-ratio test of joint significance of covariates. In addition, the panel includes the mean and median bias as summary indicators of the distribution of bias across the samples. The Rubin's B score represents the standardised difference of means of a linear index of the propensity score in treated and control firms. The Rubin's R is the ratio of treated to matched non-treated variances of the propensity score index. Values below 25 for Rubin's B, and between 0.5 and 2 for Rubin's R, are usually accepted as indicating a sufficiently balanced sample, as per the guidelines of Rosenbaum and Rubin (1985).

Table C1: Characteristics of firms Developing CARPs (1:1 Matching)

	Developed CARP	Did not develop CARP	Difference	Standard Error	T-Stat
Performance measures					
Productivity (Continuous)	259.645	238.149	21.495*	12.594	1.700
Profit growth (%)	-1.763	-11.146	9.383	10.370	0.670
Sales from exports (%)	43.036	41.251	1.784**	0.746	2.390
R&D and Innovation Measures					
R&D Intensity (Continuous)	16.967	11.037	5.930***	1.759	3.371
Internal R&D (Yes, No)	0.804	0.650	0.153***	0.042	3.610
Share of R&D employees (%)	13.536	10.326	3.209*	2.032	1.750
Sales from innovation (%)	13.586	8.667	4.918**	1.844	2.670
Digital readiness (Yes, No)	0.497	0.351	0.145***	0.045	3.200
Market Pressure Measures					
Public sector supplier (Yes, No)	0.396	0.404	-0.007	0.046	-0.160
Export (Yes, No)	0.907	0.841	0.065**	0.032	2.020
Managerial Resources					
Size of Board of Directors (Continuous)	4.155	3.968	0.187	0.393	0.480
Females on Board (%)	0.053	0.050	0.002	0.019	0.120
Female CEO/Chair (Yes, No)	0.097	0.090	0.007	0.027	0.280
External Links					
Established links HEIs (Yes, No)	0.276	0.221	0.055**	0.028	1.960

Note: *p < 0.1; **p < 0.05; ***p < 0.01. Estimation results based on a 1:1 nearest neighbour matching approach. The coefficients in 'Difference' relate to the difference between firms that developed CARPs and firms that did not develop CARPs.. See Table 2 in the main body of the paper for a detailed description of all variables.

Table C2: Characteristics of firms Developing CARPs (1:3 Matching, including those firms answering don't know to the question about CARPs)

	Developed CARP	Did not develop CARP	Difference	Standard Error	T-Stat
Performance measures					
Productivity (Continuous)	259.572	206.540	53.031**	22.334	2.370
Profit growth (%)	-2.250	-21.116	18.865**	9.251	2.040
Sales from exports (%)	41.563	42.811	-1.248	2.851	-0.440
R&D and Innovation Measures					
R&D Intensity (Continuous)	16.886	11.764	5.121***	1.193	3.610
Internal R&D (Yes, No)	0.805	0.680	0.124***	0.034	3.570
Share of R&D employees (%)	13.472	11.718	1.754*	0.955	1.830
Sales from innovation (%)	13.518	10.967	2.551*	1.550	1.650
Digital readiness (Yes, No)	0.505	0.334	0.170***	0.035	4.430
Market Pressure Measures					
Public sector supplier (Yes, No)	0.395	0.387	0.007	0.039	0.190
Export (Yes, No)	0.907	0.882	0.251**	0.091	2.750
Managerial Resources					
Size of Board of Directors (Continuous)	4.160	3.741	0.419**	0.211	1.990
Females on Board (%)	0.053	0.041	0.001	0.017	0.640
Female CEO/Chair (Yes, No)	0.097	0.095	0.001	0.002	0.070
External Links					
Established links HEIs (Yes, No)	0.277	0.184	0.093**	0.032	2.870

Notes: *p < 0.1; **p < 0.05; ***p < 0.01. Estimation results based on a 1:3 nearest neighbour matching approach. The coefficients in 'Difference' relate to the difference between firms that developed CARPs and firms that did not develop CARPs. See Table 2 for a detailed description of all variables. The main difference between this table, and Table 3 in the main body of the paper, is that this table includes 179 firms responding 'Don't Know' to the question whether they developed CARPs (as part of the category 'No').

Table D1: Characteristics of firms developing CARPs (Small-sized firms, 1:3 Matching)

	Developed CARP	Did not develop CARP	Difference	Standard Error	T-Stat
Performance measures					
Productivity (Continuous)	190.931	185.712	12.368*	7.457	1.658
Profit growth (%)	-6.350	-18.933	12.680	11.565	1.100
Sales from exports (%)	40.437	39.222	1.214	3.542	0.340
R&D and Innovation Measures					
R&D Intensity (Continuous)	27.099	17.008	10.218*	5.993	1.700
Internal R&D (Yes, No)	0.761	0.671	0.090**	0.045	1.970
Share of R&D employees (%)	17.465	16.305	1.160	2.581	0.450
Sales from innovation (%)	18.281	12.289	5.992***	0.235	2.680
Digital readiness (Yes, No)	0.510	0.379	0.138***	0.049	2.780
Market Pressure Measures					
Public sector supplier (Yes, No)	0.414	0.418	-0.004	0.049	-0.090
Export (Yes, No)	0.891	0.833	0.058**	0.023	2.520
Managerial Resources					
Size of Board of Directors (Continuous)	3.348	3.263	0.084	0.207	0.410
Females on Board (%)	0.048	0.031	0.017	0.015	1.090
Female CEO/Chair (Yes, No)	0.1441	0.093	0.051**	0.023	2.220
External Links					
Established links HEIs (Yes, No)	0.270	0.196	0.073**	0.031	2.350

Note: *p < 0.1; **p < 0.05; ***p < 0.01. Estimation results based on a 1:3 nearest neighbour matching approach considering firms with fewer than 50 employees only. The coefficients in 'Difference' relate to the difference between firms that developed and did not develop CARPs. See Table 2 in the main body of the paper for a detailed description of all variables.

Table D2: Characteristics of firms developing CARPs (Larger-sized firms, 1:3 Matching)

	Developed CARP	Did not develop CARP	Difference	Standard Error	T-Stat
Performance measures					
Productivity (Continuous)	389.522	340.656	48.866*	28.387	1.720
Profit growth (%)	3.908	-10.588	14.469*	8.649	1.670
Sales from exports (%)	42.877	41.397	1.480	4.529	0.33
R&D and Innovation Measures					
R&D Intensity (Continuous)	4.077	3.955	0.121	2.322	0.05
Internal R&D (Yes, No)	0.864	0.787	0.077**	0.033	2.330
Share of R&D employees (%)	8.326	6.485	1.840*	1.011	1.810
Sales from innovation (%)	7.473	5.708	1.765	1.15	1.250
Digital readiness (Yes, No)	0.464	0.281	0.183***	0.061	2.980
Market Pressure Measures					
Public sector supplier (Yes, No)	0.361	0.329	0.034	0.063	0.540
Export (Yes, No)	0.929	0.911	0.018	0.038	0.470
Managerial Resources					
Size of Board of Directors (Continuous)	5.246	4.469	0.777**	0.358	2.010
Females on Board (%)	0.059	0.079	-0.019	0.039	-0.490
Female CEO/Chair (Yes, No)	0.043	0.057	-0.014	0.029	-0.490
External Links					
Established links HEIs (Yes, No)	0.291	0.189	0.102**	0.051	1.960

Note: *p < 0.1; **p < 0.05; ***p < 0.01. Estimation results based on a 1:3 nearest neighbour matching approach considering firms with more than 49 employees only. The coefficients in 'Difference' relate to the difference between firms that developed and did not develop CARPs. See Table 2 in the main body of the paper for a detailed description of all variables.

Table E1: Characteristics of firms measuring CO^2 emissions (1:3 Matching)

	Measured CO_2	Did not Measure CO_2	Difference	Standard Error	T-Stat
Performance measures					
Productivity (Continuous)	285.529	225.260	60.692**	29.068	2.090
Profit growth (%)	-4.443	-4.326	-0.117	9.884	-0.010
Sales from exports (%)	38.526	37.891	0.634	3.054	0.210
R&D and Innovation Measures					
R&D Intensity (Continuous)	11.100	8.876	2.223***	0.458	4.850
Internal R&D (Yes, No)	0.793	0.697	0.095**	0.039	2.440
Share of R&D employees (%)	11.751	10.667	1.084	1.934	0.56
Sales from innovation (%)	10.801	9.974	0.827	1.669	0.50
Digital readiness (Yes, No)	0.483	0.363	0.120***	0.044	2.700
Market Pressure Measures					
Public sector supplier (Yes, No)	0.384	0.333	0.051	0.043	1.180
Export (Yes, No)	0.089	0.085	0.035	0.031	1.150
Managerial Resources					
Size of Board of Directors (Continuous)	4.698	3.867	0.830**	0.277	2.990
Females on Board (%)	0.050	0.054	-0.004	0.013	-0.300
Female CEO/Chair (Yes, No)	0.089	0.095	-0.006	0.026	-0.230
External Links					
Established links HEIs (Yes, No)	0.281	0.195	0.086**	0.038	2.220

Note: *p < 0.1; **p < 0.05; ***p < 0.01. Estimation results based on a 1:3 nearest neighbour matching approach. The coefficients in 'Difference' relate to the difference between firms that measured and firms that did not measure CO^2 emissions. See Table 2 in the main body of the paper for a detailed description of all variables. .

References

Leuven, E., and Sianesi, B. (2018) 'PSMATCH2: Stata module to perform full Mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing', *Statistical Software Components from Boston College Department of Economics*, Available at: https://github.com/eleuven/psmatch2.

Rosenbaum, P.R., and Rubin, D. (1985) 'Constructing a Control Group Using Multivariate Matched Sampling Methods that Incorporate the Propensity Score', *American Statistician*, 39, 33–38, DOI: https://doi.org/10.2307/2683903.

Download ZEW Discussion Papers:

https://www.zew.de/en/publications/zew-discussion-papers

or see:

https://www.ssrn.com/link/ZEW-Ctr-Euro-Econ-Research.html
https://ideas.repec.org/s/zbw/zewdip.html

IMPRINT

ZEW – Leibniz-Zentrum für Europäische Wirtschaftsforschung GmbH Mannheim
ZEW – Leibniz Centre for European Economic Research

L 7,1 · 68161 Mannheim · Germany
Phone +49 621 1235-01
info@zew.de · zew.de