R&D MANAGEMENT

The impact of corporate science on environmental innovations: the role of universities and research institutions

María Teresa Bolívar–Ramos

Business Department, School of Economics and Business, Autonomous University of Barcelona, Edifici B, Bellaterra (Barcelona), 08193, Spain. mariateresa.bolivar@uab.cat

Environmental innovation has become a cornerstone for companies and societies nowadays, given its potential to promote sustainable growth and development. To undertake environmental innovations, firms traditionally rely on their own resources such as corporate science, that is, basic scientific research that induces the development of the knowledge and capabilities required to sustain long-term strategies. Notably, coupled with corporate science, collaborations with universities and research institutions can also be important when seeking to promote environmental innovations, as these institutions continuously engage in R&D projects and increasingly adopt an eco-friendly vision toward innovation. The results of this longitudinal study, based on a sample of Spanish firms, confirm that corporate science investments spur environmental innovations. Yet, only collaborations with universities positively moderate the relationship between corporate science and environmental innovation.

1. Introduction

Nowadays, countries and firms around the world are taking serious actions to promote environmentally friendly strategies that help tackle societal challenges, such as climate change or resource efficiency, among others. To illustrate, on a global scale, Europe invested 76 billion US dollars on energy-efficient products and services in 2018, while China spent 61 billion US dollars and North America 47 billion US dollars (IEA, 2019). More specifically, in the European Union context, firms are supplying one third of the market for green technologies, a market whose value is €1 trillion and which is expected to double within 5 years (European Commission, 2020a).

There is a growing agreement in the literature that the development of environmental innovations leads to a 'win-win' situation where both economic and social actors benefit (Zhang and Walton, 2017; Horbach, 2019). On the one hand, firms may be better positioned to improve competitiveness and sustainability, which can translate into higher financial performance, increased reputation and improved image (Aragón-Correa and Sharma, 2003; Duanmu et al., 2018). Similarly, governments call for environmentally responsible practices to improve social well-being and sustainable growth (Bansal, 2002; Aguilera-Caracuel and Ortiz-de-Mandojana, 2013; Borghesi et al., 2015). This is why environmental innovation has become a central topic in both public and private agendas (Jové-Llopis and Segarra-Blasco, 2018; Arroyave et al., 2020; Leyva-De la Hiz and Bolívar-Ramos, 2022).

To develop environmental innovations, managers can use different strategies, such as strengthening the technological capabilities of the firm (Cainelli et al., 2012; Kesidou and Demirel, 2012). As a result, several studies have explored the role of R&D investments in driving eco-innovation (Horbach, 2008; Del Río et al., 2015; Ghisetti et al., 2015). Yet, previous research has not specifically tackled how corporate science – that is, 'basic scientific knowledge developed by for-profit firms' (Zahra et al., 2018, p. 156) – affects environmentally friendly innovations, a topic of great importance given that corporate science is key for firm competitiveness, innovation, and sustained growth (Brown, 1991; Pellens and Della Malva, 2018; Zahra et al., 2018). As environmental innovations usually require firms to master novel knowledge and diverse competences outside the current domain, that often are associated with breakthrough technological outcomes (Barbieri et al., 2020), investing in basic research may be a key input in the process.

Sometimes firms are not able to develop environmental innovations because of their lack of experience in dealing in a novel and creative way with environmental problems (Horbach, 2008). Compared to nonenvironmental innovations, eco-innovations are particularly original, involve long-term exploration with uncertain outcomes (Peters and Buijs, 2022), deal with more complex technological issues, and demand new discoveries and radical changes (De Marchi, 2012; Leyva-De la Hiz and Bolívar-Ramos, 2022). For this reason, corporate science may play a crucial role in nurturing eco-innovation given that it creates fundamentally new knowledge through basic science that, over time, can result in solutions that improve sustainable innovations (Zahra et al., 2018).

Another important factor to consider is that as the essence of environmental innovations make firms deal with a great variety of complex techno-economic problems that require diverse types of knowledge (Ghisetti et al., 2015; Barbieri et al., 2020), establishing collaborations with external partners can be decisive to eco-innovate (Messeni Petruzzelli et al., 2011; De Marchi, 2012; Díaz-García et al., 2015; Acebo et al., 2021). In this realm, different authors have pointed out that collaborations with universities and research institutes are particularly important for firms to successfully achieve eco-friendly innovations (De Marchi, 2012; Triguero et al., 2013; Jové-Llopis and Segarra-Blasco, 2018). Remarkably, these organizations not only undertake research activities and may transfer intangible inputs that compensate for the firm's internal constraints for environmental innovation, but they also connect the firm with environmentally responsible actors embedded in sustainable and eco-oriented innovation systems (Del Río et al., 2015; Ghisetti et al., 2015; Petersen and Kruss, 2021). For example, Apple collaborates with Aarhus University (Denmark) to conduct research on biomass energy generation obtained from agricultural waste products, given the long tradition of this university in this field (Apple, 2019). Little is known, however, about how the interplay between the knowledge from universities and research institutions and the scientific research developed by means of corporate science trigger environmental innovations (Arroyave et al., 2020). In a context in which eco-friendly innovations emerge from multifaceted knowledge interactions, this issue requires further investigation (Scarpellini et al., 2012; Ghisetti et al., 2015).

The objective of the research is twofold: first, it seeks to clarify and understand whether firms' investments in scientific research – that is, the primary input for sourcing novel, codified, and complex knowledge – has a positive impact on environmental innovations; and second, it explains how allying with universities and research organizations may influence the conversion of basic science investments into environmentally friendly innovations. This aspect matters as recent literature calls for deeper explanations on the role of collaborations for eco-innovation, given that 'eco-innovation studies that consider interactive effects among different external partners on firms' eco-innovation outcomes have been few and far between. Moreover, their results are contradictory' (Acebo et al., 2021, p. 2,672). Notably, much remains to be done in the environmental innovation literature to comprehend how cooperations with distinct actors influence the firm's propensity to eco-innovate (González-Moreno et al., 2019; Araújo and Franco, 2021; De Marchi et al., 2022); which particularly applies to knowledge organizations such as universities and research institutions (Arroyave et al., 2020). Thus, in line with previous arguments and research gaps, this article addresses two specific research questions: (1) does corporate science influence the development of environmental innovations, and (2) how does collaborating with universities and research institutions impact the relationship between corporate science and environmental innovations?

This study contributes to the literature in different ways. To begin with, the research advances the literature on environmental innovation with its focus on corporate science as a key internal driver that has still been largely understudied (Penders et al., 2009; Zahra et al., 2018). Notably, as eco-innovations represent a new technological frontier that tend to involve radical changes (Leyva-De la Hiz and Bolívar-Ramos, 2022), investing in scientific knowledge may be key, as it induces the creation of novel knowledge. Thus, this article provides a deeper understanding of the topic, considering that 'the issue of sources of information and knowledge used in eco-innovative activities is rarely treated in the eco-innovation literature' (Horbach et al., 2013, p. 528; Ghisetti et al., 2015, p. 1,080). Using the lens of the knowledge-based view (Grant, 1996), the results of this study show that investments in basic science, the primary input for sourcing novel knowledge, has a positive effect on the development of environmental innovations, a source of competitive advantage. In addition to that, the research contributes to understanding the role that universities and research institutions play in strengthening the relationship between corporate science and environmental innovation. Previous literature has paid attention to how organizations source scientific knowledge from universities and research institutions and how these interactions may result in greater (or lower) knowledge creation and the development of high-impact innovations (Fini et al., 2019). This study, moving a step forward, explores whether collaborations with universities and research institutions contribute to complement corporate science investments by enhancing knowledge-generation processes in an eco-innovative context. This aspect requires further attention due to the intrinsic characteristics of environmental innovations, that is, greater complexity, novelty, and radicalness compared to non-environmental ones, since eco-innovations tend to build upon novel knowledge and competences far from the current business domain that are expected to involve radical changes (Ardito et al., 2019; Barbieri et al., 2020). Due to their high degree of novelty and originality, collaborations with scientific partners may be critical for enhancing the development of environmental innovations. Thus, this research contributes to the recent literature on eco-innovation that calls for the need to analyze in depth how the interactions with different collaborators and open-innovation strategies affect firms' eco-innovation (Acebo et al., 2021), with a focus on scientific partners (i.e., universities and research institutions). In doing so, the research also contributes to advancing the current underdeveloped area of research on how green outputs from public research institutions may stimulate firms' generation of environmentally friendly outcomes (Ardito et al., 2019). Last, this article addresses an increasing demand in public policies around the world – for example, the Environment Action Program to 2020, in the European Union – that calls for the need to understand how to promote innovations that help to protect the natural environment.

The article is structured as follows. Section 2 presents the theory and hypotheses of the study. Then, Sections 3 and 4 explain the research methodology, empirical analyses, and results. The last two sections discuss the main conclusions and implications of the study, as well as its main limitations.

2. Theoretical background and hypotheses

Environmental innovation[1] refers to 'the development of products, processes, and services aimed at reducing environmental harm by using new methods for treating emissions, recycling or reusing waste, finding cleaner energy sources, and so on' (Brunnermeier and Cohen, 2003; Berrone et al., 2013, p. 891). Typically, environmental innovations involve the introduction of new or improved goods or services, processes, marketing solutions, or organizational changes that lower the utilization of natural resources (e.g., materials, water, energy, and land) and reduce the release of hazardous substances throughout the life cycle (Eco-Innovation Observatory, 2011; Leyva-de la Hiz et al., 2019). These types of innovations tend to be affected by internal and external drivers, which include technology push, market pull, and institutional factors (Horbach, 2008, 2016; Triguero et al., 2013; Borghesi et al., 2015; Jové-Llopis and Segarra-Blasco, 2018).

It is generally accepted that environmental innovation adds value for society and firms in a world in which the protection of the environment has become critical (Aguilera-Caracuel and Ortiz-de-Mandojana, 2013; Berrone et al., 2013; Del Río et al., 2015; Zhang and Walton, 2017; European Commission, 2020a; Acebo et al., 2021). To illustrate, let us consider the investments in clean energies over the last years, mainly dominated by solar and wind energies. The wind power sector alone got over 131 billion US dollars in 2018. In a similar way, global investments in solar energy technologies increased from 10.7 billion US dollars in 2004 to approximately 141 billion US dollars in 2018, with Europe, China, and the United States taking the lead (Statista, 2020a). Moreover, institutions are doing considerable efforts to support eco-innovation and sustainable growth through different strategies and political measures, such as the United Nations' Sustainable Development

Goals (SDGs), the Eco-innovation Action Plan (Eco AP, 2011), and the Europe 2020 Strategy (European Commission, 2020b), which in turn is giving firms additional incentives to develop and uptake eco-friendly innovations.

In a business context, environmental innovations help companies achieve competitive advantage either through cost leadership or differentiation (Díaz-García et al., 2015). Moreover, the exploitation of eco-innovations can increase benefits based on a rise in sales, a better positioning in the market (Triguero et al., 2013; Doran and Ryan, 2016), and improvements in financial performance, firm competitiveness, and growth (Bansal and Gao, 2006). A clear example is Tesla, a pioneer in the manufacture and sale of fully electric vehicles, which has become a brand associated with energy saving. It had revenue of $17.6 billion US dollars from vehicle sales in 2018 and delivered globally 112,000 units by the end of the fourth quarter of 2019 alone (Statista, 2020b).

It is important to note that firms' commitment to develop environmental innovations is highly conditioned by managers' attitudes and motivation toward implementing an eco-friendly and sustainable orientation within firms (Lampikoski et al., 2014; Díaz-García et al., 2015). In this sense, the literature has paid attention to some of the most common strategies firms undertake to promote eco-innovation, highlighting the role that R&D investments and collaborations play (Messeni Petruzzelli et al., 2011; De Marchi, 2012; Del Río et al., 2015; Acebo et al., 2021), as discussed next.

The contribution of R&D investments to environmental innovation is well accepted in the literature. Horbach (2016) showed that enhancing technological capabilities through internal R&D investments improves eco-innovation. Similarly, Ghisetti et al. (2015) found that firm's engagement in R&D activities increases their likelihood of developing environmentally friendly innovations. In a similar way, Jové-Llopis and Segarra-Blasco (2018) proved that by increasing the pool of knowledge available in the firm, R&D efforts stimulate eco-innovation. These studies provide important empirical insights consistent with the innovation literature but do not sufficiently articulate what the specific role of corporate science is in nurturing environmental innovations.

Corporate science refers to 'business companies' funded, officially sanctioned and supported, discovery-driven research aimed at developing basic new knowledge' (Zahra et al., 2018, p. 157). Generally, firms invest in scientific research not only to facilitate the creation of new products and processes but also to improve the absorption of external knowledge and technologies (Zahra and George, 2002; Arora et al., 2015, 2018). Consequently, firms tend to be better positioned to introduce radical inventions that promise higher financial returns and competitive advantage (Simeth and Cincera, 2015). In an environmental context, scientific knowledge has to be a decisive force to create solutions to the challenges faced by society, including climate change and environmental protection, which justifies research actions as a top priority for achieving eco-innovation results (European Union, 2020). This is why companies such as Tesla and other vehicle manufacturers undertake R&D plans in order to develop cars that produce lower polluting emissions, enhance energy efficiency, and decrease the adoption of fossil fuels in transportation (EU R&D Scoreboard, 2019). As corporate science differs from traditional R&D activities, because it is specifically directed toward creating fundamentally new knowledge and sustaining long lead time and riskier projects that define the firm's key strategic objectives (Rosenbloom and Kantrow, 1982), exploring the connection between corporate science and the development of eco-friendly innovations requires further attention.

As mentioned previously, it is important to note that environmental innovations happen in fast-changing business environments that entail continuous resource configurations and the engagement of other agents and institutions to overcome firms' internal limitations (Triguero et al., 2013; Watson et al., 2018; Arroyave et al., 2020). For this reason, environmental innovations usually require greater collaborative effort since developing products or services with lower environmental impact represents a technological frontier; it is a quite complex task that usually involves new, distant knowledge and skills, unfamiliar to the firm, in a context of high market and technological uncertainty (Messeni Petruzzelli et al., 2011; De Marchi, 2012; Díaz-García et al., 2015; Acebo et al., 2021). In this scenario, and from all the potential external knowledge sources, previous scholars have emphasized that collaborations with universities and research institutions tend to be particularly valuable for introducing eco-innovations (De Marchi, 2012; Triguero et al., 2013; Jové-Llopis and Segarra-Blasco, 2018; Arroyave et al., 2020). To illustrate, the European Green Vehicle Initiative (EGVI) is a collaborative project that unites 82 members from industry, research institutes, and academia, with the objective of accelerating the research and development required to boost the transition to greener road transportation (European Commission, 2020c). Within industry members, there are companies from the automotive industry, some others devoted to engineering, the production of smart systems, and the deployment of smart electricity grids. In relation to the research members, research institutes and universities working in the field of road transport technologies develop an active role (EGVI, 2020). So, although eco-innovation may be undertaken by firms, collaborations with universities and research institutions can accelerate the process and reduce risk and uncertainties, thereby contributing to successful results (Scarpellini et al., 2012). Yet, few studies in the literature have provided enough evidence on how cooperation with universities and research organizations can affect environmental innovations (Watson et al., 2018). The reason for analyzing these two institutions is that, along with the private sector, they tend to conform to the national system of science, technology, and innovation in different countries (OECD, 1997), and, as such, not only are they knowledge-creating entities, but they also contribute to the transformation of inventions into final products.

In sum, consistent with the innovation literature, there is broad consensus on the fact that research investment and engagement in collaborations are key drivers of eco-innovations, although a more novel and specific approach to analyze how they affect environmentally friendly innovations is still required (Messeni Petruzzelli et al., 2011; Marzucchi and Montresor, 2017). In fact, little is known about how these internal and external factors interact and potentially constitute environmental innovation drivers (Ghisetti et al., 2015). To be more concrete, the next section analyzes what the role of investments in basic science is in fostering environmental innovation. Thus, the study sheds some light on how knowledge resources affect eco-innovation outcomes, considering the paucity of empirical research on the topic (Zhang and Walton, 2017). Further, it also explains how collaborations with universities and research institutions may moderate such relationships, as scientific partners may stimulate firms' efforts to generate novel environmental technologies (Ardito et al., 2019; Arroyave et al., 2020), that require fundamentally new approaches. Overall, the study contributes to a more general goal: understanding under what conditions firms develop environmental innovations (Berrone et al., 2013).

2.1. The impact of corporate science on environmental innovation

R&D spending plays a key role in the realization of environmental innovations (Horbach, 2008; Borghesi et al., 2015; Ghisetti et al., 2015). To provide a few examples, companies' R&D investments are critical to creating more efficient wind turbines to generate more energy, to develop improved batteries to be implemented in electric cars, or to achieve reductions in greenhouse gas emissions (EU R&D Scoreboard, 2019). Yet, as noted in the innovation literature, 'R' and 'D' can have differential effects on innovation (Barge Gil and López, 2014a). For this reason, the corporate science literature addresses the role of firms' scientific research investments in driving strategic long-term purposes (Rosenbloom and Kantrow, 1982; Nelson, 1987; Arora et al., 2015), such as environmental innovation activities.

As Barbieri et al. (2020) have recently discussed, based on the results of a study on a large sample of patents filed over the period 1980–2012, green technologies are more complex and also involve a greater degree of novelty than nongreen technologies, given that they typically entail a new technological frontier that requires significant changes due to the absence of technological trajectories. In other words, green patents are characterized by integrating more novel and diverse technological inputs and components than their nongreen counterparts (Ghisetti et al., 2015; Leyva-De la Hiz and Bolívar-Ramos, 2022). Usually, the development of environmentally friendly products is a complex activity that is built upon diverse knowledge bases that fall outside the traditional industry knowledge domain (De Marchi, 2012). Thus, eco-innovation requires greater exploration in new technological dimensions that goes beyond the well-known and already exploited technologies (Zhang and Walton, 2017). Considering that companies may struggle when facing these radical and complex environmental challenges that imply the need to develop novel knowledge and capabilities (Cecere et al., 2014), investing in corporate science may act as a critical input for the development of new technologies (Arora et al., 2018), in this case, environmental ones.

In general terms, and to what the 'technology-push' effect refers, environmental innovations have been typically associated with a firm's knowledge capital (Horbach, 2008; De Marchi, 2012; Doran and Ryan, 2016; Kiefer et al., 2019). By investing in basic science, firms support the development of discoveries that provide solutions to unsolved problems and create knowledge that informs new recombinations that breed innovation and a firm's competitive advantage and growth (Zahra et al., 2018). For instance, the German company Bosch, while acknowledging climate change as one of the megatrends that affects our current lives, indicates that 'without research, there can be no progress. And without progress, we cannot improve the quality of people's lives' (Bosch Research, 2020). To keep that commitment, the company has developed research centers that work on topics such as intelligent energy management, among others, in strategic locations, and supports researchers working on scientific publications published in top-tier journals as a basic input for innovation.

Corporate science also builds scientific capabilities that facilitate the understanding of complex technological landscapes (Arora et al., 2018), thereby improving the appraisal of applied findings in a more accurate way (Fleming and Sorenson, 2001; Pellens and Della Malva, 2018). Given that environmental innovations are less path-dependent than other types of innovations (which makes existent knowledge difficult to apply), firms may need to promote new knowledge development to a greater extent (Ghisetti et al., 2015; Kiefer et al., 2019; Barbieri et al., 2020), which can be achieved through investments in scientific research. In fact, corporate science may be key to the development of eco-innovative technologies, as in many cases these are at the earlier stages of their life cycle (Consoli et al., 2016) and therefore require novel knowledge inputs to face multifaceted and recent problems (Marzucchi and Montresor, 2017; Leyva-De la Hiz and Bolívar-Ramos, 2022).

It is important to note that managers' vision can condition how much companies invest in promoting eco-friendly innovations (Lampikoski et al., 2014; Díaz-García et al., 2015). Agency problems (among manager-owners, or managers-scientists) may determine the extent to which firms are willing to spend on basic science to pursue scientific challenges associated with lower environmental impacts (Baysinger and Hoskisson, 1990; Leyva-de la Hiz et al., 2019), as managers may feel tempted to give priority to short-term goals rather than riskier and more demanding projects. Further, previous studies have indicated that companies do not invest enough in research projects and rely more on external sources, which can be explained by the low productivity they associate with in-house research investments (Scarpellini et al., 2012; Arora et al., 2015, 2018), thus also affecting eco-innovative initiatives. This, in turn, could weaken the link between corporate science investments and environmental innovations development.

Despite previous arguments, there is evidence that investments in basic research are crucial to keep producing cutting-edge technologies and innovations to address world sustainability challenges (UNESCO Science Report, 2015). Currently, firms are aware that eco-innovations can bring benefits to society and firms (Díaz-García et al., 2015; Arroyave et al., 2020), and that may provide an incentive to invest in corporate science as a necessary input to promote discovery and guide these long-term strategic objectives. Indeed, investments in basic science condition the direction of innovations and guide new initiatives that exploit unmet customers' demands, creating first-mover advantages and improvements in firm reputation in contexts in which the protection of the natural environment is required (Kiefer et al., 2019). Thus,

Hypothesis 1 Investments in corporate science are positively associated with environmental innovation.

2.2. *The moderating role of collaborations with universities and research institutions in relation between corporate science and environmental innovation*

Previous research has pointed out the importance of networking with other partners and research institutions for eco-innovation development (Cainelli et al., 2012; Díaz-García et al., 2015; Norberg-Bohm, 2000; Watson et al., 2018). In fact, engaging in collaborations that promote external knowledge acquisition tends to be even more relevant for environmental innovations than for other types of innovations (Horbach, 2016; Acebo et al., 2021). This can be explained by the high uncertainty, complexity, and degree of newness associated with environmentally friendly innovations, that go beyond firm's traditional knowledge base and core competences (Jové-Llopis and Segarra-Blasco, 2018; Barbieri et al., 2020). Environmental innovations require firms to face different techno-economic problems, such as the adoption of particular engineering knowledge, compliance with environmental standards, the development of sustainable inputs, among others, that entail knowledge requirements hard to satisfy exclusively by means of internal sources (Foster and Green, 2000; Ghisetti et al., 2015). This is why the complementarities between internal research efforts and external collaboration strategies can be considered a key factor to succeed (De Marchi, 2012; Doran and Ryan, 2016).

Despite the broad range of collaborations in which firms can engage to pursue environmental innovations, the literature shows that universities and research institutions are among the most valuable partners to achieve this goal (De Marchi, 2012; Triguero et al., 2013; Arroyave et al., 2020). To provide an example, Telefónica, a Spanish telecommunications group serving around 350 million customers, considers critical to collaborate with public and private research institutions, as well as universities, to promote initiatives oriented toward developing innovations that meet the United Nations' Sustainable Development Goals, including environmental targets (Telefónica, 2020). Certainly, many eco-innovative fields, such as electro mobility or renewable energies are relatively new, and this makes them especially dependent on basic research activities and external knowledge inputs provided by universities and research institutions (Horbach, 2016). It is worth mentioning that, in situations in which, in occasions, firms seem to be reluctant to pursue eco-innovation goals, universities and research institutes may constitute key partners to promote connections between the private sector and society needs (Scarpellini et al., 2012). Yet, little is known on how these two internal and external sources interact, in part because of the previous unavailability of data to study corporate science; a basic component within R&D (Ghisetti et al., 2015; Kiefer et al., 2019).

Universities have been traditionally conceived as institutions that work hard to create innovative solutions (Perkmann et al., 2013; Fischer et al., 2019), that have a positive impact on society at large, empower world citizens, protect the natural environment, and fuel the economy (European University Association, 2019). To illustrate, Harvard University, through the Sustainability Plan 2015–2020, has set clear objectives in the fields of emissions and energy, nature and ecosystems, and encourages faculty and staff to pilot sustainable solutions by applying Harvard's leading-edge research and teaching to solve world challenges (Harvard University, 2020). Thus, it is hardly surprising to see that leading companies that promote environmental innovations currently engage in collaborations with universities to achieve this goal. Such is the case of Iberdrola, one of the most important players in Spain in the field of renewable energies, which collaborates with the Massachusetts Institute of Technology (MIT) to support innovation in the field of clean energies.

As previously introduced, firm investments in R&D and participating in collaborations with universities have traditionally been associated with an improvement in environmental innovation outcomes (Cainelli et al., 2012; Scarpellini et al., 2012; Doran and Ryan, 2016; Acebo et al., 2021). Drawing upon a database that covers 27 European countries, Triguero et al. (2013) showed that collaborations with universities are critical to promoting all kinds of eco-innovation, and this is why public authorities promote networks between firms and universities to support this goal (such as the European Innovation Partnership). In particular, by investing in corporate science, firms make substantial contributions to the scientific knowledge required to approach complex environmental problems. However, it is the interplay with universities' engagement that may potentiate environmental innovations, given that firms can materialize science into successful outcomes through collaborations with scientific partners that allow them to access cutting-edge technologies and advanced R&D activities, human capital, and infrastructures, thereby diminishing the costs of internalizing them (Acebo et al., 2021). Further, green technologies developed by public research organizations, such as universities, reflect the public environmental knowledge and opportunities that firms can acquire to complement internal research efforts, thus facilitating the subsequent technological development and fostering the transition of firms toward more eco-friendly innovative activities (Ardito et al., 2019). Thus, over the last years, the number of research collaborations between universities and firms have grown considerably, as firms can enhance their research performance by gaining access to the best scientific and engineering minds, which is key to eco-innovate (Arroyave et al., 2020).

Yet, the process of acquiring the knowledge and experience provided by universities for eco-innovative practices may not be successful. This, in turn, could interfere in the success of corporate science initiatives for environmental purposes. As Scarpellini et al. (2012) discuss, there is still a considerable gap between firms and universities as researching organizations, and their different motivations affect environmental innovations. More specifically, these authors indicate that universities usually present complex structures, making it complicated for firms to connect with the right expert to acquire specific knowledge. In addition, sometimes firm professionals do not rely on university research, which is perceived as 'disconnected' from the private world (Sjöö and Hellström, 2021). Also, in relation to the firm, the scarcity of managerial competences for processing green-specific inputs could pose important challenges to environmental innovation processes (Ghisetti et al., 2015).

Although there may be different plausible explanations, the reality shows that the interaction between internal and external sources of knowledge tends to be critical for eco-innovation, as firms can develop internally tacit and codified knowledge, which is difficult to transfer, but can also absorb externally distant knowledge (Kiefer et al., 2019). In particular, investments in basic scientific research can nurture and support long-term environmental innovation objectives (Leyva-de la Hiz et al., 2019). Simultaneously, collaborations with universities may strengthen the success of these organizational processes, as universities make an important contribution by developing a sustainable orientation, teaching and training staff on how to conduct basic research, and generating scientific knowledge that can be transferred to an ecosystem in which multiple stakeholders participate (Ferraris et al., 2018; Petersen and Kruss, 2021). In general, over the last decade, firms have increased their cooperation with universities to transform their basic knowledge and scientific research into applied knowledge to create value for society through sustainable projects (Acebo et al., 2021). Thus,

> **Hypothesis 2** The positive association between corporate science and environmental innovation strengthens when firms collaborate with universities.

research institutions, whether public or private, also constitute knowledge-generating entities that spur innovation activities. As specified in the Oslo Manual (2018), a public research institution/organization is one that 'performs R&D as a primary economic activity (research); and (ii) it is controlled by government (formal definition of public sector)' (p. 140). Besides public research organizations, it is useful to account for private research institutes since these are typically highly dependent on direct or indirect government funds for their R&D plans. Thus, in this study, the term 'research institutions' was inclusive of these two organizations.

Over the last years, research institutions have been supporting sustainable goals while simultaneously connecting with firms to speed up the development of eco-innovations. Let us illustrate this by looking at 'ICB' (The Carbon Chemistry Institute), which is one of the institutes that integrates the 'CSIC' (National Council of Scientific Research) in Spain. ICB's research activities involve great social sensitivity (CO2 capture/climate change, waste recovery), according to new technological challenges (production of hydrogen and renewable fuels) and cutting-edge applications (nanoscience and nanotechnology, development of new sensors, batteries, fuel cells, etc.) (ICB, 2020). This institute has five research groups; it is currently executing 96 research projects and possesses 69 patents that signal the knowledge transfer activities of this organization. As a result, firms such as SISENER have collaborated with the ICB to develop new processes focused on increasing waste recovery and improving the value of certain raw materials in order to exploit the maximum potential of their research activities (ICB, 2018).

As discussed, by investing in basic scientific research, firms develop a source of knowledge and capabilities that define the basis for their long-term strategies (Pellens and Della Malva, 2018; Hartmann and Henkel, 2020). In that context, collaborations with research institutions may be critical to influence a firm's strategic orientation toward environmental innovation for different reasons. First, research institutions can provide important knowledge requirements, such as the scientific knowledge that firms need in relation to the materials to be used in environmental innovations (Ghisetti et al., 2015), while also training researchers and applying for patents in green fields. In addition, research institutions sometimes present a multidisciplinary approach that can also benefit the multifaceted nature of environmental innovations (Triguero et al., 2013). Moreover, research institutions traditionally pursue economic and social development, so these organizations can play a key role in supporting 'green' initiatives through grants, research programs, or collaborations with the private sector, in an attempt to boost their development by stimulating the basic scientific knowledge underlying them (Wagner, 2007; Zahra et al., 2018).

We cannot ignore that the potential contributions of firms to scientific knowledge that spurs environmental innovations may not be without problems. In particular, concerns about the appropriability of basic research outcomes coupled with the difficulties associated with developing environmental innovations, namely, greater risks, complexity, and uncertainty (Berrone et al., 2013; Leyva-de la Hiz et al., 2019), may discourage firms from engaging in these initiatives (Arora et al., 2015). Consequently, firms may find additional incentives to pursue short-term innovations that are incremental in nature (Lazonick and Tulum, 2011; Arora et al., 2015), and they may use their collaborative efforts to this end. Aside from that, in the basic research stage, R&D project managers may encounter administrative barriers that can translate into constraints regarding funding (i.e., grants), which in turn can negatively affect the selection of environmental projects and the success of collaborations with research institutions (Polzin et al., 2016).

Despite the persistence of some contradictory arguments, the interplay between corporate science and collaborations with research institutions may still result in positive effects for environmental innovations (Arroyave et al., 2020). Notably, research institutions play a key translational role in connecting basic and applied research (Popp, 2017). Along these lines, agencies and research institutions have been found to positively influence material and energy eco-processes innovations (Horbach et al., 2013; Triguero et al., 2013). In addition, research institutions can shape and affect firms' corporate science investments in order to promote environmentally friendly innovations with high potential and social value (Zahra et al., 2018). When firms invest in the development of eco-innovations, they may be able to benefit from network externalities as well in the form of environmental-knowledge spillovers that, in turn, affect the incentives for eco-innovation (Fritsch and Franke, 2004; Cainelli et al., 2012). Thus,

> **Hypothesis 3** The positive association between corporate science and environmental innovation strengthens when firms collaborate with research institutions.

3. Methodology

3.1. Data

This study was based on the panel data obtained from PITEC (*Panel de Innovación Tecnológica*), collected by the National Statistics Institute of Spain in line with the guidelines of the Community Innovation Survey. The reason for choosing Spain as the geographical context of the research and this specific database is justified by different reasons. First, previous studies have pointed to the increasing importance of environmental issues in the Spanish economy, making this setting appropriate to explore and analyze eco-innovation dynamics (De Marchi, 2012; Del Río et al., 2015; Marzucchi and Montresor, 2017). Second, one of the main difficulties encountered in studying corporate science is the scarcity of data (Díaz-García et al., 2015). However, PITEC is useful in overcoming this limitation, as it contains separate information about the amounts of scientific research and development. Further, this panel database offered a wide range of variables related to technological and eco-innovation activities (explained in the next section), which allowed us to test the empirical model proposed. An additional aspect to point out is that PITEC has been widely used in innovation studies that analyze environmental strategies (Horbach, 2016; Jové-Llopis and Segarra-Blasco, 2018).

In this research, the firm constituted the unit of analysis. The sample of this study was restricted to Spanish innovative firms (i.e., reporting positive intramural R&D expenditures), as the aim of the research required companies to be engaged in research and development activities (Barge Gil and López, 2014b; Gimenez-Fernandez et al., 2020). The dataset used in this study was obtained from the combination of six panel waves of PITEC (2012, 2013, 2014, 2015, and 2016), that covered the period 2010–2016. It is important to note that the questionnaire for each survey wave in time *t* included data from time *t*-2 to *t*. To illustrate, in the wave of 2016, there is data on the firm's business year 2016, although some items also collected information on a 3-year period (e.g., collaborations with universities, from 2014 to 2016). When this was the case, specific information has been provided in the description of variables and measures. After the filtering process mentioned before, the result was an unbalanced panel of 4,064 firms and 15,208 observations, which ensured a representative sample of Spanish firms, in line with recent eco-innovation studies in this context (Acebo et al., 2021). Regarding firm characteristics, 78.53% of them represented small- and medium-sized enterprises, whereas 21.47% were large firms (i.e., possess more than 250 employees). Yet, only 6.11% constituted new ventures (i.e., less than 10 years), in contrast with 93.89% for established firms. In terms of the firms' international scope, 75.73% do not engage in international collaborations, while 24.27% cooperate with foreign partners in a single geographical area (16.31%) or two or more areas (7.97%).[2] It is also worth noting that 49.87% belong to a group. Finally, as Table 1 displays, over the 2010–2016 period, around 12% of the firms in the sample invested in corporate science, and approximately 58% had introduced environmental innovations. Notably, just focusing on the group of eco-innovators, around 65% of the firms reported expenditures on basic scientific research.

Table 1. Sample statistics (proportion of firms per year)

	2010	2011	2012	2013	2014	2015	2016
Firms with corporate science	12.44%	13.04%	11.49%	10.16%	10.78%	12.71%	12.17%
Firms that eco-innovate	59.39%	56.95%	56.75%	58.39%	58.78%	58.32%	58.96%
Eco-innovators that invest in corporate science[1]	66.9%	62.7%	62.6%	66.13%	70.30%	65.20%	65.85%

[1]Percentage of firms with respect to the group of environmental innovators.

3.2. Variables

3.2.1. Dependent variable

3.2.1.1. Environmental innovation

In line with recent research, this study measured environmental innovation using a PITEC question that asks firms to indicate on a 4-item scale to what extent the firm has introduced any innovations aimed at reducing environmental impact. The responses were then coded into a binary variable that took the value 1 if the firm introduced any innovation with a medium or strong reduction in environmental impact in the preceding 3 years; and 0 if not (Acebo et al., 2021). This dependent variable and measure are consistent with previous studies and existing literature on the topic that also used PITEC and followed a similar approach (De Marchi, 2012; Marzucchi and Montresor, 2017). Further, using a dummy as a dependent variable, it was possible to compare the results of the study with previous research on the topic using Community Innovation Survey (CIS) datasets (De Marchi, 2012; Martínez-Ros and Kunapatarawong, 2019). For the empirical analyses, the longitudinal nature of the data made it possible to introduce a 2-year lag between all the independent variables and the firm's environmental innovation to lessen concerns over endogeneity and account for the time that has elapsed since firms invested in corporate science until they might be able to introduce eco-innovations.

3.2.2. Independent and moderator variables

3.2.2.1. Corporate science

Corporate science has been recently defined as 'business companies' funded, officially sanctioned, and supported, discovery driven research aimed at developing basic new knowledge' (Zahra et al., 2018, p. 157; Hartmann and Henkel, 2020). This conceptualization distinguishes corporate science from corporate R&D, as the former focuses on the discovery of basic scientific knowledge by firms. Thus, considering the availability of data, and this conceptualization, the variable corporate science was measured using the logarithm of the basic research intensity; that is, basic research investments divided by the number of employees.

3.2.2.2. Cooperation with universities

To measure this specific collaboration, the study relied on the binary variable provided by PITEC that reflects whether firms collaborated with universities in the preceding 3 years, coded as 1 and 0 if not (De Marchi, 2012).

3.2.2.3. Cooperation with research institutions

In line with the approach mentioned before, the study relied on the binary variable provided by PITEC that reflects whether firms collaborated with research institutions (public/private) in the preceding 3 years, coded as 1 and 0 if not (De Marchi, 2012).

3.2.3. Control variables

The study also included a set of control variables that could affect the relationships proposed (Barge Gil and López, 2014a; Doran and Ryan, 2016). First, the analysis controlled for industry effects, considering firms in high, medium-high, medium-low, and low technology industries, in line with the OECD ISIC Rev.3 technology intensity definition, in an approach that has already been followed by past research on eco-innovation (Triguero et al., 2013; Acebo et al., 2021). Second, firm age was considered because older and younger firms tend to present different innovative behaviors (Huergo and Jaumandreu, 2004). Firm age was measured by the number of years the firm had been operating since it was founded (in logarithms). Third, another variable taken into account was firm's exports, measured by the natural logarithm of the export investments, as the literature suggests that a high export performance can induce environmental innovations (Ghisetti et al., 2015). Fourth, along with it, the study controlled for the international scope of collaborations, as it is becoming common that firms cross their national frontiers to acquire knowledge inputs that reside in other countries and can be useful in generating eco-innovations. This variable captures the number of distinct geographical areas in which firms have international partners, considering Europe, U.S.A., China/India, and other countries, as established by the PITEC questionnaire (Arranz et al., 2020). Fifth, the study included a binary control variable that took the value of 1 when the firm belonged to a group, and 0 otherwise. Sixth, the analysis controlled for the total personnel working on R&D, measured by the logarithm of the number of employees working specifically on R&D activities. In addition to that, the training expenditures were also considered. This variable was measured by the logarithm of the total expenditures devoted to training programs aimed at increasing employees' abilities to develop new or significantly improved products. Notably, researchers and their training and skills not only affect the quality of research discoveries (Zahra et al., 2018), but also influence environmental innovations because the education of the workforce is expected to exert a positive impact on environmentally proactive strategies (Keshminder and del Río, 2019). Another control variable included was external R&D intensity, that is, the ratio of the total external R&D expenditures divided by the number of employees (in logarithms).

The reason is that, typically, the higher the pool of knowledge resources and technological capabilities available within the firm, the higher the probability of introducing environmental innovations (Doran and Ryan, 2016). This is why the number of patents in logarithms was added as another control variable. Moreover, the analysis accounts for firm size, using the logarithm of the firm turnover (Leyva-de la Hiz et al., 2019). Firm size may condition environmental innovations because SMEs tend to have lower levels of resources than large firms, which can affect eco-innovative activities that are usually quite costly. As an additional control variable, the inclusion of past environmental innovations was also relevant because past eco-innovation behavior is usually a driver of current environmental innovations (Acebo et al., 2021). This was measured by a binary variable that took the value of 1 when the firm had developed environmental innovations in the three previous years, and 0 otherwise. Further, the study controlled for environmental regulation, which is one of the key policy factors that affects a firm's eco-innovation activities. Specifically, this is a binary variable that equals 1 when the firm innovation objective has a strong or medium orientation toward meeting environmental regulation requirements and 0 if not (Jové-Llopis and Segarra-Blasco, 2018). In addition, other R&D expenditures, including applied research and technological development, were also set as a control variable, by taking the total amount of other R&D expenditures divided by the number of employees (in logs). Finally, the analyses included a set of year dummies to control for time.

4. Analysis and results

Table 2 displays the descriptive statistics, including the means and standard deviations, and also the correlation matrix. As expected, corporate science, cooperation with universities, and cooperation with research institutions are positively and significantly correlated with environmental innovation. Moreover, in relation to the rest of the correlations, none of them is excessively high. Variance inflation factors were computed and confirmed that collinearity was not a problem, as the factors were between 1.06 and 2.8 and therefore below the acceptable threshold of five or 10 (O'Brien, 2007).

Since the dependent variable (environmental innovation) is a binary variable, estimations were done using probit regressions, which is consistent with past research (Horbach, 2016). As the study relies on panel data, the random effects model was an appropriate technique for solving the incidental parameter problem that characterizes binary data panel models (Croissant and Millo, 2018). Initially, the base model simply included the control variables. Then, model 2 added the independent variables. Finally, given the need to test for the moderation effects, interaction terms were introduced in models 3, 4, and 5. Table 3 shows the results of the empirical analyses.

In the base model (model 1) in Table 3, we can observe that medium-high and medium-low technology sectors, international scope of collaborations, personnel working on R&D activities, training expenditures, patents, firm size, past environmental innovations, environmental regulation, and other R&D expenditures, as control variables, had a positive and significant impact on environmental innovation. However, although the level of exports is likely to affect the likelihood of being an innovative firm, it did not affect eco-innovations (Marzucchi and Montresor, 2017). Moreover, external R&D did not have a significant impact on environmental innovation, which is in line with the results obtained by Doran and Ryan (2016) in the sense that extramural R&D does not always positively affect all types of eco-innovation. Finally, firm age and belonging to a group did not exert a significant effect on the introduction of environmental innovations.

In model 2, the results show that investments in basic scientific research positively and significantly affected environmental innovation ($\beta = 0.012$, $P < 0.05$). Hence, Hypothesis 1, which stated that corporate science is positively associated with environmental innovation, was supported. The new knowledge and discoveries induced by corporate science investments are thus key to increasing the likelihood of developing environmental innovations.

The moderating role of collaborations with universities and research institutions on the relationship between corporate science and environmental innovation was analyzed in the next models. In particular, model 3 tested the moderating effect of collaborations with universities, that can only be confirmed if (and only if) this interaction term is significant (Dawson, 2014, p. 2). As the coefficient of the interaction term was positive and significant ($\beta = 0.017$, $P < 0.1$), Hypothesis 2 was supported. Thus, cooperating with universities strengthens the association between corporate science and environmental innovation. However, as model 4 shows, the moderating effect of collaborations with research institutions was positive but not significant ($\beta = 0.006$), which means that Hypothesis 3 was not supported. In other words, and contrary to what was expected, engaging in collaborations with research institutions did not strengthen the relationship between corporate science and environmental innovation. Specifically, the

Table 2. Descriptive statistics and correlations

Variables	Mean	SD	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1) Environmental innovation	0.59	0.49	1.000																	
(2) High-tech	0.24	0.43	−0.143*	1.000																
(3) Medium-high tech	0.27	0.44	0.090*	−0.325*	1.000															
(4) Medium-low tech	0.14	0.34	0.051*	−0.220*	−0.237*	1.000														
(5) Firm age_lg	3.33	0.55	0.105*	−0.265*	0.153*	0.107*	1.000													
(6) Total exports_lg	11.61	6.74	0.117*	−0.162*	0.246*	0.156*	0.255*	1.000												
(7) International scope	0.39	0.79	0.129*	0.112*	−0.007	−0.035*	0.026*	0.149*	1.000											
(8) Group	0.51	0.49	0.091*	−0.075*	0.017*	0.043*	0.130*	0.198*	0.194*	1.000										
(9) Personnel in R&D_lg	2.38	1.09	0.137*	0.205*	−0.050*	−0.080*	0.092*	0.184*	0.381*	0.307*	1.000									
(10) Training expenditures_lg	1.72	3.61	0.081*	0.056*	−0.007	−0.039*	0.021*	0.025*	0.163*	0.050*	0.167*	1.000								
(11) External RD_lg	2.65	3.51	0.085*	0.099*	−0.019*	−0.031*	−0.030*	0.064*	0.229*	0.101*	0.273*	0.118*	1.000							
(12) Patents (number)_lg	0.25	0.64	0.088*	0.073*	0.056*	−0.012	0.033*	0.147*	0.269*	0.100*	0.326*	0.099*	0.178*	1.000						
(13) Size_lg	16.28	2.13	0.193*	−0.271*	0.066*	0.097*	0.415*	0.384*	0.207*	0.499*	0.441*	0.086*	0.080*	0.146*	1.000					
(14) Environmental regulation	0.61	0.49	0.662*	−0.118*	0.118*	0.033*	0.084*	0.120*	0.126*	0.061*	0.106*	0.089*	0.078*	0.094*	0.148*	1.000				
(15) Other R&D expenditures_lg	12.77	1.59	−0.001	0.335*	0.013*	−0.123*	−0.238*	−0.031*	0.157*	−0.115*	0.283*	0.041*	0.229*	0.131*	−0.367*	0.016*	1.000			
(16) Corporate science	1.35	3.75	0.051*	0.115*	−0.023*	−0.033*	−0.025*	−0.007	0.112*	−0.020*	0.134*	0.064*	0.084*	0.114*	−0.020*	0.050*	0.022*	1.000		
(17) Cooperation with universities	0.22	0.41	0.110*	0.120*	−0.091*	−0.081*	−0.059*	−0.006	0.377*	0.070*	0.295*	0.121*	0.259*	0.188*	0.086*	0.098*	0.158*	0.093*	1.000	
(18) Cooperation with research institutions	0.43	0.20	0.075*	0.049*	−0.057*	−0.038*	−0.031*	−0.009	0.258*	0.056*	0.184*	0.102*	0.164*	0.115*	0.078*	0.075*	0.085*	0.076*	0.247*	1.000

*$P < 0.05$.

Table 3. Probit models results – Dependent variable: Environmental innovation

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
High-technology	−0.331***	−0.337***	−0.339***	−0.337***	−0.339***
	(0.066)	(0.066)	(0.066)	(0.066)	(0.066)
Medium-high technology	0.208***	0.222***	0.223***	0.222***	0.223***
	(0.062)	(0.062)	(0.063)	(0.062)	(0.063)
Medium-low technology	0.144*	0.159**	0.158**	0.159**	0.158**
	(0.076)	(0.075)	(0.076)	(0.076)	(0.076)
Firm age_lg	0.053	0.058	0.057	0.058	0.057
	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)
Total exports_lg	0.003	0.003	0.003	0.003	0.003
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
International scope	0.105***	0.071**	0.069**	0.071**	0.069**
	(0.029)	(0.031)	(0.031)	(0.031)	(0.031)
Group	−0.079	−0.073	−0.072	−0.073	−0.072
	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)
Personnel in R&D_lg	0.094***	0.077***	0.078***	0.077***	0.078***
	(0.028)	(0.029)	(0.029)	(0.029)	(0.029)
Training expenditures_lg	0.012**	0.011**	0.011**	0.011**	0.011**
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
External R&D_lg	0.009	0.006	0.006	0.006	0.006
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Patent (number)_lg	0.060*	0.051	0.050	0.051	0.050
	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
Size_lg	0.104***	0.106***	0.105***	0.106***	0.105***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Past environmental innovation_lg	0.791***	0.788***	0.788***	0.788***	0.788***
	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)
Environmental regulation	0.257***	0.252***	0.252***	0.252***	0.252***
	(0.044)	(0.044)	(0.044)	(0.044)	(0.044)
Other R&D expenditures_lg	0.029*	0.032*	0.031*	0.032*	0.031*
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Corporate science		0.012**	0.006	0.011**	0.006
		(0.005)	(0.006)	(0.005)	(0.006)
Cooperation with universities		0.149***	0.125**	0.149***	0.124**
		(0.048)	(0.050)	(0.048)	(0.051)
Cooperation with research institutions		0.036	0.033	0.024	0.034
		(0.059)	(0.059)	(0.063)	(0.064)
Corporate science × Cooperation with universities			0.017*		0.017*
			(0.010)		(0.010)
Corporate science × Cooperation with research institutions				0.006	−0.000
				(0.011)	(0.012)
Year	Yes	Yes	Yes	Yes	Yes
Constant	−2.908***	−2.908***	−2.871***	−2.905***	−2.871***
	(0.374)	(0.374)	(0.375)	(0.374)	(0.375)
Observations	15,208	15,208	15,208	15,208	15,208
Number of ident	4064	4064	4064	4064	4064

Standard errors in parentheses.
***$P<0.01$,
**$P<0.05$,
*$P<0.1$.

results confirmed that universities are more valuable partners to increase the benefits of corporate science investments for environmentally friendly innovations. These findings support the critical role of universities in environmental innovations, as already discussed by Cainelli et al. (2012) and De Marchi (2012) but differ in relation to the role of research institutions. The reason may be that although both types of organizations complement a firm's internal knowledge resources that spur innovation activities, research institutions may still fall behind universities in promoting environmental objectives.

Finally, an additional test with the two interaction terms was performed (model 5). Results show that under these circumstances, only the moderating role of collaborations with universities was positive and significant ($\beta = 0.017$, $P < 0.1$). Thus, these findings corroborate that universities are more relevant partners in increasing the chances of developing environmental innovations from corporate science investments.

In addition to previous results, as it is difficult to interpret an interaction term in nonlinear models, such as Probit (Ai and Norton, 2003; Zelner, 2009), it is necessary to compute and plot the marginal effects. This is what Figure 1 reflects, in relation to the moderating role of collaboration with universities. As we can observe, the plot confirms that corporate science investments positively affect the likelihood to eco-innovate, and this propensity is even stronger when firms cooperate with universities. This provides further support for Hypothesis 2.

4.1. Robustness tests

To evaluate the robustness of the results reported, additional analyses were carried out. Table 4 reports a robustness test consisting of taking an alternative measure of the dependent variable 'environmental innovation'. In particular, 'environmental innovation 2' considered whether firms reported whether innovations that reduced environmental impact and complied with regulatory environmental standards were important/high in time 't+2' (coded as 1) or not (coded as 0) (Loredo et al., 2019). Using a different specification, this eco-innovation variable allowed us to mitigate potential problems and to test whether the results of the analyses were robust (Martínez-Ros and Kunapatarawong, 2019).

As we can observe in Table 4, the main results of the study regarding the impact of corporate science on environmental innovation and the moderating role of collaborations with universities and research institutions remained unchanged. That is, corporate science has a positive and significant effect on the likelihood of developing environmental innovations. However, only collaborations with universities positively and significantly affected the relationship between corporate science and environmental innovations.

5. Discussion and conclusions

Over the last years, the literature has shown that firms pursuing environmental innovations can improve their financial performance and corporate image, increase sales, achieve competitive advantage, exploit opportunities in new markets, and contribute to sustainability goals (Porter and van der Linde, 1995; Aguilera-Caracuel and Ortiz-de-Mandojana, 2013; Doran and Ryan, 2016; Duanmu et al., 2018). For these reasons, firms and government organizations are including environmental innovations as one of their key strategic lines

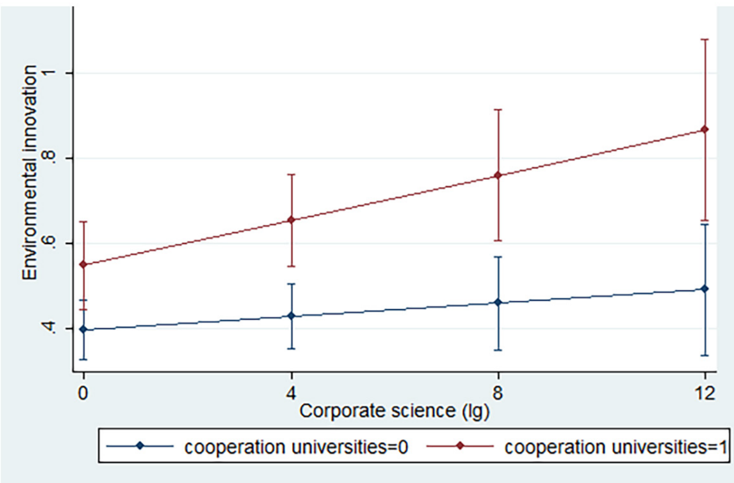

Figure 1. The moderating effect of collaboration with universities.

Table 4. Robustness test – Dependent variable: Environmental innovation 2

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
High-technology	0.253***	−0.261***	−0.263***	−0.261***	−0.263***
	(0.070)	(0.070)	(0.070)	(0.070)	(0.070)
Medium-high technology	0.308***	0.321***	0.322***	0.321***	0.322***
	(0.066)	(0.066)	(0.066)	(0.066)	(0.066)
Medium-low technology	0.163**	0.176**	0.175**	0.176**	0.175**
	(0.079)	(0.079)	(0.079)	(0.079)	(0.079)
Firm age_lg	0.083*	0.087*	0.087*	0.087*	0.087*
	(0.047)	(0.047)	(0.047)	(0.047)	(0.047)
Total exports_lg	0.006*	0.007**	0.007**	0.007**	0.007**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
International scope	0.071**	0.041	0.038	0.041	0.038
	(0.029)	(0.031)	(0.031)	(0.031)	(0.031)
Group	−0.083	−0.077	−0.075	−0.077	−0.075
	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
Personnel in R&D_lg	0.089***	0.071**	0.073**	0.071**	0.073**
	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)
Training expenditures_lg	0.017***	0.016***	0.016***	0.016***	0.016***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
External R&D_lg	0.006	0.004	0.004	0.004	0.004
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Patent (number)_lg	0.057*	0.049	0.048	0.049	0.048
	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
Size_lg	0.093***	0.096***	0.095***	0.096***	0.095***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Past environmental innovation_lg	0.617***	0.612***	0.613***	0.612***	0.613***
	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)
Environmental regulation	0.374***	0.371***	0.370***	0.371***	0.370***
	(0.047)	(0.047)	(0.047)	(0.047)	(0.047)
Other R&D expenditures_lg	0.033*	0.038**	0.036**	0.037**	0.036**
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Corporate science		0.015***	0.008	0.014***	0.009
		(0.005)	(0.006)	(0.005)	(0.006)
Cooperation with universities		0.121**	0.095*	0.121**	0.094*
		(0.049)	(0.051)	(0.049)	(0.051)
Cooperation with research institutions		0.066	0.063	0.058	0.069
		(0.059)	(0.059)	(0.063)	(0.063)
Corporate science × Cooperation with universities			0.018*		0.019*
			(0.010)		(0.010)
Corporate science × Cooperation with research institutions				0.004	−0.003
				(0.011)	(0.012)
Year	Yes	Yes	Yes	Yes	Yes
Constant	−3.145***	−3.145***	−3.098***	−3.142***	−3.098***
	(0.383)	(0.383)	(0.384)	(0.383)	(0.384)
Observations	15,208	15,208	15,208	15,208	15,208
Number of ident	4,064	4,064	4,064	4,064	4,064

Standard errors in parentheses.
***$P<0.01$,
**$P<0.05$,
*$P<0.1$.

(Zhang and Walton, 2017; Jové-Llopis and Segarra-Blasco, 2018). Given that knowledge-based factors and collaborations play a prominent role in promoting environmentally friendly innovations (Triguero et al., 2013; Horbach, 2016; Acebo et al., 2021), this study has explored the following research questions: does corporate science affect the development of environmental innovations, and how do collaborations with universities and research institutions influence the relationship between corporate science and environmental innovations?

In line with Hypothesis 1, the results of the empirical analyses confirm that firms investing in corporate science are more likely to undertake environmental innovations. Recent research has already tackled how 'research' and 'development' investments, taken separately, affect innovative outcomes, with a special emphasis on how investments in basic science affect product/process or incremental/radical innovations (Barge Gil and López, 2014a). However, this study moves a step forward, as it discusses how corporate science, the primary driver of discovery, affects environmental innovations. In comparison with standard innovations, eco-innovations typically rely on more novel knowledge inputs, which depart from current technological trajectories and which demand original and radically new solutions (Barbieri et al., 2020). Thus, understanding how investments in basic science may induce eco-friendly innovations requiring a higher degree of exploration, and capable of being nurtured by scientific research, merit special attention. Further, this topic is critical nowadays, since preserving the natural environment through innovation has become a key goal for multiple stakeholders in modern societies (Fliaster and Kolloch, 2017; Watson et al., 2018; Leyva-De la Hiz and Bolívar-Ramos, 2022) and has inspired numerous policies worldwide (e.g., SDGs, Eco-Innovation Action Plan, and so on). In particular, the study has shown that despite its uncertain outcomes, fostering corporate science improves the chances to develop eco-innovation, because it helps delineate long-term goals, that require particularly creative and novel solutions based on new knowledge recombinations that move away from existing knowledge and lead to innovations that reduce environmental hazards. These results thus contribute to a greater understanding of how some internal firm resources – that is, corporate science – impact environmental innovation, a topic that has been rarely considered due to the lack of available data to perform econometric analyses (Díaz-García et al., 2015).

In line with Hypothesis 2, the results show that the relation between corporate science and environmental innovations becomes stronger when firms cooperate with universities. However, contrary to what it was expected in Hypothesis 3, the findings of the research reveal that collaborating with research institutions does not positively moderate the relationship between corporate science and environmental innovations. Indeed, environmental innovations require more basic research and external sources of knowledge, given their association with relatively new technologies (Del Río et al., 2015; Barbieri et al., 2020). The fact that only collaborations with universities reinforce the corporate science and environmental innovation relationship could be explained by their unique role in promoting basic scientific research, education, and highly talented personnel committed to assisting firms in developing sustainable innovative solutions (European University Association, 2019). On the contrary, it may be plausible that research institutions, despite offering valuable knowledge and guidance for firms, may help companies in developing innovations that do not necessarily pursue environmental objectives to a greater extent. This result may be surprising, given that research institutes, for example, CSIC in Spain, are becoming top organizations in promoting sustainable goals framed within policy programs such as Horizon 2020 in the European Union. Yet, it is still partly consistent with past research, as Doran and Ryan (2016) found that public links (universities and research institutions) have no significant impact on eco-innovations. Overall, the results of this study provide a more fine-grained explanation by showing how universities and research institutions can differently affect/condition a firm's long-term research goals and environmental strategies. In this sense, corporate science investments may be more valuable in fostering environmental innovation when their development occurs along with university support, which is consistent with the idea that most basic research originates in universities.

From a theoretical standpoint, this study extends the knowledge-based view literature (Grant, 1996) by showing how intangible, complex, and valuable knowledge assets embedded in corporate science can contribute to developing environmental innovations, which are sources of competitive advantage for firms in modern societies (Zahra et al., 2018). Remarkably, only recently has research focused on explaining how different types of knowledge inputs that firms obtain or develop affect eco-friendly innovations (Cainelli et al., 2015; Marzucchi and Montresor, 2017; Acebo et al., 2021). Moreover, the study also contributes to understanding under what conditions firms benefit from collaborations with research organizations that can provide novel knowledge inputs for eco-friendly innovations while also supporting an environmentally responsible culture (Arroyave et al., 2020). Specifically, our findings are consistent with previous research which highlights that external knowledge inputs do not always lead to a 'one-size-fits-all' strategy in the environmental literature (Ghisetti et al., 2015) given that only collaborations with universities strengthen a firm's ability to develop environmental innovations through corporate science investments.

Aside from the theoretical contributions previously discussed, this study also presents several implications for managers and policymakers. In relation to managerial implications, as corporate science drives environmental innovations, it is important that managers willing to implement eco-friendly innovations adopt a vision that supports corporate science spending as a strategic goal (Díaz-García et al., 2015; Leyva-de la Hiz et al., 2019). This tends to be one of the greatest obstacles to the success of corporate science programs. Moreover, to reap more benefits from research investments in environmental innovations, firms need to work more closely with universities, which is consistent with past studies' results (Cainelli et al., 2012; De Marchi and Grandinetti, 2013; Triguero et al., 2013). It is important to note that as the collaborations between universities and firms are not exempt of misalignments, technology centers (that link public and private firms) can play the role of environmental vectors since these institutions facilitate speeding up a firm's innovative process while reducing uncertainty and risks (Scarpellini et al., 2012). In this way, firms may be better positioned to acquire, understand, and absorb the knowledge sources these valuable institutions provide, which in turn will complement corporate science outputs.

Regarding policy implications, identifying the modes of knowledge that lead to environmental innovation can help policymakers make decisions to support firms in pursuing this goal (Ghisetti et al., 2015). Environmental innovations' positive effects extend beyond firm boundaries since they contribute to reducing environmental challenges for society, including global warming and declining resources or pollution, among others (Leyva-De la Hiz and Bolívar-Ramos, 2022). Given that governments fund research projects developed by institutions such as universities, laboratories, and the private sector, the insights from this study can be helpful to inform where public research funds should be targeted to promote green initiatives (Popp, 2017). Specifically, the findings suggest that public authorities should not only stimulate firms' environmental innovation efforts through corporate science but should also encourage interactions with universities to improve successful results. These findings are consistent with recent policy programs, such as the European Innovation Partnership, a specific action that belongs to the Eco-innovation Action Plan, and whose main goal is to boost cooperation between public and private stakeholders to enhance eco-innovations (Triguero et al., 2013).

6. Limitations and future research

This study presents some limitations that offer opportunities for future research. First, as environmental innovation is context-specific, future research should analyze the proposed model in different countries (Díaz-García et al., 2015) other than Spain. This would help us understand how context/country-specific characteristics affect the relationship between corporate science and environmental innovation as well as the moderating role of collaborations with research organizations.

In addition, although the variable that measures environmental innovation has been previously used in the literature (Marzucchi and Montresor, 2017; Acebo et al., 2021), which is helpful to provide comparative studies that enrich this field (Martínez-Ros and Kunapatarawong, 2019), it neither gives us information on how many environmental innovations firms develop nor on whether these innovations are radical or incremental, or related to product or process innovations. Thus, to measure eco-innovation, future research should include variables that capture realized environmental innovations with a more specific focus, beyond the classical approach of studies using CIS surveys that consider firm's environmental objectives in technological-innovative activities, in order to provide a richer and useful extension of this work. Also, to deepen our knowledge about the relationship between corporate science and environmental innovation and to advance overall the environmental innovation literature (Horbach et al., 2013; Kiefer et al., 2019). Another interesting point is that since the information provided by PITEC to measure collaborations with research organizations (i.e., universities and research institutions) is based on a binary variable, future research should consider how intense or frequent these collaborations are to shed some light on this relevant topic.

Finally, this research specifically focuses on how the interplay between corporate science and external knowledge sources provided by universities and research institutions influence firms' environmentally responsible innovation activities. However, it would be interesting to explore the moderating role of collaborations with other partners, such as suppliers or competitors, which can also contribute to open eco-innovation practices (Doran and Ryan, 2016; Horbach, 2016). As previously discussed, recent studies have underlined the need to investigate the sources of knowledge that breed eco-innovations, a topic that is underestimated in the environmental innovation literature (Ghisetti et al., 2015).

Acknowledgements

I thank Shaker A. Zahra for his help and excellent comments that contributed to significantly improve this article. I would also like to thank the anonymous reviewers for their valuable suggestions. This work was supported by the Spanish Ministry of Economy, Industry and Competitiveness (grant numbers ECO2017-87885-P, ECO2017-86054-C3-1-R, and PID2020-114460GB-C31).

Data availability statement

Research data are not shared.

REFERENCES

Acebo, E., Miguel-Dávila, J.Á., and Nieto, M. (2021) External stakeholder engagement: complementary and substitutive effects on firms' eco-innovation. *Business Strategy and the Environment*, **30**, 2671–2687.

Aguilera-Caracuel, J. and Ortiz-de-Mandojana, N. (2013) Green innovation and financial performance: an institutional approach. *Organization & Environment*, **26**, 4, 365–385.

Ai, C. and Norton, E. (2003) Interaction terms in logit and probit models. *Economic Letters*, **80**, 1, 123–129.

Apple. (2019) Environmental Responsibility Report, 2019.

Aragón-Correa, J.A. and Sharma, S. (2003) A contingent resource-based view of proactive corporate environmental strategy. *Academy of Management Review*, **28**, 1, 71–88.

Araújo, R. and Franco, M. (2021) The use of collaboration networks in search of eco-innovation: a systematic literature review. *Journal of Cleaner Production*, **314**, 127975.

Ardito, L., Petruzzelli, A.M., and Ghisetti, C. (2019) The impact of public research on the technological development of industry in the green energy field. *Technological Forecasting and Social Change*, **144**, 25–35.

Arora, A., Belenzon, S., and Patacconi, A. (2015) *Killing the Golden Goose? The Decline of Science in Corporate R&D*, NBER Working Paper 20902. Cambridge, MA: National Bureau of Economic Research.

Arora, A., Belenzon, S., and Patacconi, A. (2018) The decline of science in corporate R&D. *Strategic Management Journal*, **39**, 1, 3–32.

Arranz, N., Arroyabe, M., Li, J., and Fernandez de Arroyabe, J.C. (2020) Innovation as a driver of eco-innovation in the firm: an approach from the dynamic capabilities theory. *Business Strategy and the Environment*, **29**, 3, 1494–1503.

Arroyave, J.J., Sáez-Martínez, F.J., and González-Moreno, Á. (2020) Cooperation with universities in the development of eco-innovations and firms' performance. *Frontiers in Psychology*, **11**, 1–9.

Bansal, P. (2002) The corporate challenges of sustainable development. *Academy of Management Executive*, **16**, 122–131.

Bansal, P. and Gao, J. (2006) Building the future by looking to the past: examining research published on organizations and environment. *Organization & Environment*, **19**, 4, 458–478.

Barbieri, N., Marzucchi, A., and Rizzo, U. (2020) Knowledge sources and impacts on subsequent inventions: do green technologies differ from non-green ones? *Research Policy*, **49**, 2, 103901.

Barge Gil, A. and López, A. (2014a) R versus D: estimating the differentiated effect of research and development on innovation results. *Industrial and Corporate Change*, **24**, 1, 93–129.

Barge-Gil, A. and López, A. (2014b) R&D determinants: accounting for the differences between research and development. *Research Policy*, **43**, 9, 1634–1648.

Baysinger, B. and Hoskisson, R.E. (1990) The composition of boards of directors and strategic control: effects on corporate strategy. *Academy of Management Review*, **15**, 1, 72–87.

Berrone, P., Fosfuri, A., Gelabert, L., and Gomez-Mejia, L.R. (2013) Necessity as the mother of 'green' inventions: institutional pressures and environmental innovations. *Strategic Management Journal*, **34**, 8, 891–909.

Borghesi, S., Cainelli, G., and Mazzanti, M. (2015) Linking emission trading to environmental innovation: evidence from the Italian manufacturing industry. *Research Policy*, **44**, 3, 669–683.

Bosch Research. (2020) [online] Available from https://www.bosch.com/research/

Brown, J.S. (1991) Research that reinvents the corporation. *Harvard Business Review*, **68**, 1, 102–111.

Brunnermeier, S.B. and Cohen, M.A. (2003) Determinants of environmental innovation in US manufacturing industries. *Journal of Environmental Economics and Management*, **45**, 2, 278–293.

Cainelli, G., De Marchi, V., and Grandinetti, R. (2015) Does the development of environmental innovation require different resources? Evidence from Spanish manufacturing firms. *Journal of Cleaner Production*, **94**, 211–220.

Cainelli, G., Mazzanti, M., and Montresor, S. (2012) Environmental innovations, local networks and internationalization. *Industry and Innovation*, **19**, 8, 697–734.

Cecere, G., Corrocher, N., Gossart, C., and Ozman, M. (2014) Lock-in and path dependence: an evolutionary approach to eco-innovations. *Journal of Evolutionary Economics*, **24**, 5, 1037–1065.

Consoli, D., Marin, G., Marzucchi, A., and Vona, F. (2016) Do green jobs differ from non-green jobs in terms of skills and human capital? *Research Policy*, **45**, 5, 1046–1060.

Croissant, Y. and Millo, G. (2018) *Panel Data Econometrics*. Hoboken, NJ: John Wiley & Sons.

Dawson, J.F. (2014) Moderation in management research: what, why, when, and how. *Journal of Business and Psychology*, **29**, 1, 1–19.

De Marchi, V. (2012) Environmental innovation and R&D cooperation: empirical evidence from Spanish manufacturing firms. *Research Policy*, **41**, 3, 614–623.

De Marchi, V. and Grandinetti, R. (2013) Knowledge strategies for environmental innovations: the case of Italian manufacturing firms. *Journal of Knowledge Management*, **17**, 4, 569–582.

De Marchi, V., Molina-Morales, F.X., and Martínez-Cháfer, L. (2022) Environmental innovation and cooperation: a configurational approach. *Technological Forecasting and Social Change*, **182**, 121835.

Del Río, P., Peñasco, C., and Romero-Jordán, D. (2015) Distinctive features of environmental innovators: an econometric analysis. *Business Strategy and the Environment*, **24**, 6, 361–385.

Díaz-García, C., González-Moreno, Á., and Sáez-Martínez, F.J. (2015) Eco-innovation: insights from a literature review. *Innovation*, **17**, 1, 6–23.

Doran, J. and Ryan, G. (2016) The importance of the diverse drivers and types of environmental innovation for firm performance. *Business Strategy and the Environment*, **25**, 2, 102–119.

Duanmu, J.L., Bu, M., and Pittman, R. (2018) Does market competition dampen environmental performance? Evidence from China. *Strategic Management Journal*, **39**, 11, 3006–3030.

Eco AP. (2011) *The Eco-Innovation Action Plan*. [online] Available from https://ec.europa.eu/environment/ecoap/about-action-plan/objectives-methodology

Eco-Innovation Observatory (2011) *The Eco-Innovation Challenge: Pathways to a Resource-Efficient Europe*. Brussels: EIO.

EGVI. (2020) *European Green Vehicle Initiative: Full Members*. [online] Available from https://egvi.eu/who-we-are/membership/

EU R&D Scoreboard. (2019). The 2019 EU Industrial R&D Investment Scoreboard.

European Commission. (2020a) *Eco-Innovation at the Heart of European Policies*. [online] Available from https://ec.europa.eu/environment/ecoap/about-action-plan/objectives-methodology_en

European Commission. (2020b) *Europe 2020. A European Strategy for Smart, Sustainable and Inclusive Growth*. [online] Available from https://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf

European Commission. (2020c) *Public-Private Partnerships in Energy*. [online] Available from https://ec.europa.eu/info/research-and-innovation/research-area/energy-research-and-innovation/public-private-partnerships-energy_en

European Union. (2020) *Valorisation. Making Results Work for Society*. [online] Available from https://ec.europa.eu/info/sites/info/files/research_and_innovation/strategy_on_research_and_innovation/documents/ec_rtd_valorisation_factsheet.pdf

European University Association. (2019) [online] Available from https://eua.eu/118-uncategorised/731-eua-focus-group-on-universities-in-innovation-ecosystems-apply-now.html

Ferraris, A., Belyaeva, Z., and Bresciani, S. (2018) The role of universities in the Smart City innovation: multistakeholder integration and engagement perspectives. *Journal of Business Research*, **119**, 163–171.

Fini, R., Rasmussen, E., Wiklund, J., and Wright, M. (2019) Theories from the lab: how research on science commercialization can contribute to management studies. *Journal of Management Studies*, **56**, 865–894.

Fischer, B.B., Schaeffer, P.R., and Vonortas, N.S. (2019) Evolution of university-industry collaboration in Brazil from a technology upgrading perspective. *Technological Forecasting and Social change*, **145**, 330–340.

Fleming, L. and Sorenson, O. (2001) Technology as a complex adaptive system: evidence from patent data. *Research Policy*, **30**, 7, 1019–1039.

Fliaster, A. and Kolloch, M. (2017) Implementation of green innovations – the impact of stakeholders and their network relations. *R&D Management*, **47**, 5, 689–700.

Foster, C. and Green, K. (2000) Greening the innovation process. *Business Strategy and the Environment*, **9**, 5, 287–303.

Fritsch, M. and Franke, G. (2004) Innovation, regional knowledge spillovers and R&D cooperation. *Research Policy*, **33**, 2, 245–255.

Ghisetti, C., Marzucchi, A., and Montresor, S. (2015) The open eco-innovation mode. An empirical investigation of eleven European countries. *Research Policy*, **44**, 5, 1080–1093.

Gimenez-Fernandez, E.M., Sandulli, F.D., and Bogers, M. (2020) Unpacking liabilities of newness and smallness in innovative start-ups: investigating the differences in innovation performance between new and older small firms. *Research Policy*, **49**, 10, 104049.

González-Moreno, Á., Triguero, Á., and Sáez-Martínez, F.J. (2019) Many or trusted partners for eco-innovation? The influence of breadth and depth of firms' knowledge network in the food sector. *Technological Forecasting and Social Change*, **147**, 51–62.

Grant, R.M. (1996) Toward a knowledge-based theory of the firm. *Strategic Management Journal*, **17**, S2, 109–122.

Hartmann, P. and Henkel, J. (2020) The rise of corporate science in AI: data as a strategic resource. *Academy of Management Discoveries*, **6**, 3, 359–381.

Harvard University. (2020) *Harvard Sustainability Plan 2015–2020*. [online] Available from https://green.harvard.edu/campaign/our-plan

Horbach, J. (2008) Determinants of environmental innovation – New evidence from German panel data sources. *Research Policy*, **37**, 1, 163–173.

Horbach, J. (2016) Empirical determinants of eco-innovation in European countries using the community innovation survey. *Environmental Innovation and Societal Transitions*, **19**, 1–14.

Horbach, J. (2019) Determinants of eco-innovation at the firm level. In: *Handbook of Sustainable Innovation*. London: Edward Elgar Publishing.

Horbach, J., Oltra, V., and Belin, J. (2013) Determinants and specificities of eco-innovations compared to other innovations – an econometric analysis for the French and German industry based on the community innovation survey. *Industry and Innovation*, **20**, 6, 523–543.

Huergo, E. and Jaumandreu, J. (2004) How does probability of innovation change with firm age? *Small Business Economics*, **22**, 3–4, 193–207.

ICB. (2018) [online] Available from https://www.icb.csic.es/en/noticias/ramon-murillo-participa-en-el-lanzamiento-de-un-nuevo-tratamiento-de-residuos/

ICB. (2020) *The carbon chemistry institute*. [online] Available from https://www.csic.es/en/investigacion/institutos-centros-y-unidades/carbon-chemistry-institute

IEA (2019, November 5) Value of investments in energy efficiency technologies worldwide from 2014 to 2018, by region (in billion U.S. dollars)* [graph]. In: *Statista*. [online] Available from https://www.statista.com/statistics/731947/global-energy-efficient-investments-by-region/ [Accessed 18 March 2020]

Jové-Llopis, E. and Segarra-Blasco, A. (2018) Eco-innovation strategies: a panel data analysis of Spanish manufacturing firms. *Business Strategy and the Environment*, **27**, 8, 1209–1220.

Keshminder, J.S. and del Río, P. (2019) The missing links? The indirect impacts of drivers on eco-innovation. *Corporate Social Responsibility and Environmental Management*, **26**, 5, 1100–1118.

Kesidou, E. and Demirel, P. (2012) On the drivers of eco-innovations: empirical evidence from the UK. *Research Policy*, **41**, 5, 862–870.

Kiefer, C.P., Del Río González, P., and Carrillo-Hermosilla, J. (2019) Drivers and barriers of eco-innovation types for sustainable transitions: a quantitative perspective. *Business Strategy and the Environment*, **28**, 1, 155–172.

Lampikoski, T., Westerlund, M., Rajala, R., and Möller, K. (2014) Green innovation games: value-creation strategies for corporate sustainability. *California Management Review*, **57**, 1, 88–116.

Lazonick, W. and Tulum, Ö. (2011) US biopharmaceutical finance and the sustainability of the biotech business model. *Research Policy*, **40**, 9, 1170–1187.

Leyva-De la Hiz, D.I. and Bolívar-Ramos, M.T. (2022) The inverted U relationship between green innovative activities and firms' market-based performance: The impact of firm age. *Technovation*, **110**, 1–10.

Leyva-de la Hiz, D.I., Ferron-Vilchez, V., and Aragon-Correa, J.A. (2019) Do firms' slack resources influence the relationship between focused environmental innovations and financial performance? More is not always better. *Journal of Business Ethics*, **159**, 1215–1227.

Loredo, E., Lopez-Mielgo, N., Pineiro-Villaverde, G., and García-Álvarez, M.T. (2019) Utilities: innovation and sustainability. *Sustainability*, **11**, 4, 1085.

Martínez-Ros, E. and Kunapatarawong, R. (2019) Green innovation and knowledge: the role of size. *Business Strategy and the Environment*, **28**, 6, 1045–1059.

Marzucchi, A. and Montresor, S. (2017) Forms of knowledge and eco-innovation modes: evidence from Spanish manufacturing firms. *Ecological Economics*, **131**, 208–221.

Messeni Petruzzelli, A., Maria Dangelico, R., Rotolo, D., and Albino, V. (2011) Organizational factors and technological features in the development of green innovations: evidence from patent analysis. *Innovation: Organization & Management*, **13**, 3, 291–310.

Nelson, D. (1987) "Corporate science" [Review of the making of American industrial research: science and business at GE and bell]. *Reviews in American History*, **15**, 1, 105–108.

Norberg-Bohm, V. (2000) Creating incentives for environmentally enhancing technological change: lessons from 30 years of US energy technology policy. *Technological Forecasting and Social Change*, **65**, 2, 125–148.

O'Brien, R.M. (2007) A caution regarding rules of thumb for variance inflation factors. *Quality and Quantity*, **41**, 5, 673–690.

OECD. (1997) *National innovation systems*. [online] Available from http://www.oecd.org/science/inno/2101733.pdf

Oslo Manual. (2018) *Guidelines for collecting, reporting and using data on innovation*.

Pellens, M. and Della Malva, A. (2018) Corporate science, firm value, and vertical specialization: evidence from the semiconductor industry. *Industrial and Corporate Change*, **27**, 3, 489–505.

Penders, B., Verbakel, J.M., and Nelis, A. (2009) The social study of corporate science: a research manifesto. *Bulletin of Science, Technology & Society*, **29**, 6, 439–446.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., Fini, R., Geuna, A., Grimaldi, R., Hughes, A., Krabel, S., Kitson, M., Llerena, P., Lissoni, F., Salter, A., and Sobrero, M. (2013) Academic engagement and commercialisation: a review of the literature on university–industry relations. *Research Policy*, **42**, 2, 423–442.

Peters, K. and Buijs, P. (2022) Strategic ambidexterity in green product innovation: obstacles and implications. *Business Strategy and the Environment*, **31**(1), 173–193.

Petersen, I.H. and Kruss, G. (2021) Universities as change agents in resource-poor local settings: an empirically grounded typology of engagement models. *Technological Forecasting and Social Change*, **167**, 120693.

Polzin, F., von Flotow, P., and Klerkx, L. (2016) Addressing barriers to eco-innovation: exploring the finance mobilisation functions of institutional innovation intermediaries. *Technological Forecasting and Social Change*, **103**, 34–46.

Popp, D. (2017) From science to technology: the value of knowledge from different energy research institutions. *Research Policy*, **46**, 9, 1580–1594.

Porter, M.E. and van der Linde, C. (1995) Green and competitive. *Harvard Business Review*, **73**, 5, 120–134.

Rosenbloom, R.S. and Kantrow, A.M. (1982) *Nurturing of corporate research*. Harvard Business Review. Retrieved from https://hbr.org/1982/01/the-nurturing-of-corporate-research

Scarpellini, S., Aranda, A., Aranda, J., Llera, E., and Marco, M. (2012) R&D and eco-innovation: opportunities for closer collaboration between universities and companies through technology centers. *Clean Technologies and Environmental Policy*, **14**, 6, 1047–1058.

Simeth, M. and Cincera, M. (2015) Corporate science, innovation, and firm value. *Management Science*, **62**, 7, 1970–1981.

Sjöö, K. and Hellström, T. (2021) The two sides of the coin: joint project leader interaction in university-industry collaboration projects. *R&D Management*, **51**, 5, 484–493.

Statista. (2020a) Global investment in solar energy technologies from 2004 to 2018. [online] Available from https://www.statista.com/statistics/186823/global-investment-in-solar-technology-since-2004/#statisticContainer

Statista. (2020b) *Number of Tesla Vehicles Delivered Worldwide from 4th Quarter 2015 to 1st Quarter 2020*. [online] Available from https://www.statista.com/statistics/502208/tesla-quarterly-vehicle-deliveries/

Telefónica. (2020) [online] Available from https://www.telefonica.com/web/negocio-responsable/-/contenido-emprendimiento-innovacion

Triguero, A., Moreno-Mondéjar, L., and Davia, M.A. (2013) Drivers of different types of eco-innovation in European SMEs. *Ecological Economics*, **92**, 25–33.

UNESCO. (2015) *UNESCO Science Report: Towards 2030*. [online] Available from http://www.unesco.org/new/en/member-states/single-view/news/what_is_the_optimal_balance_between_basic_and_applied_resear/

Wagner, M. (2007) On the relationship between environmental management, environmental innovation and patenting: evidence from German manufacturing firms. *Research Policy*, **36**, 10, 1587–1602.

Watson, R., Wilson, H.N., Smart, P., and Macdonald, E.K. (2018) Harnessing difference: a capability-based framework for stakeholder engagement in environmental innovation. *Journal of Product Innovation Management*, **35**, 2, 254–279.

Zahra, S.A. and George, G. (2002) Absorptive capacity: a review, reconceptualization, and extension. *Academy of Management Review*, **27**, 2, 185–203.

Zahra, S.A., Kaul, A., and Bolívar-Ramos, M.T. (2018) Why corporate science commercialization fails: integrating diverse perspectives. *Academy of Management Perspectives*, **32**, 1, 156–176.

Zelner, B. (2009) Using simulation to interpret results from logit, probit and other nonlinear models. *Strategic Management Journal*, **30**, 12, 1335–1348.

Zhang, J.A. and Walton, S. (2017) Eco-innovation and business performance: the moderating effects of environmental orientation and resource commitment in green-oriented SMEs. *R&D Management*, **47**, 5, E26–E39.

Notes

[1] In this article, the terms 'environmental', 'eco', or 'green' innovation will be used interchangeably for two main reasons: (a) this is the approach followed by a considerable number of researchers, and (b) 'environmental', 'green', and 'eco-innovation' all focus on innovations that aim to reduce the negative impact of economic activities in the environment (Díaz-García et al., 2015).

[2] PITEC differentiates collaborations with partners in five different geographical areas: national (Spain), Europe, U.S.A., China/India, and others.

María Teresa Bolívar–Ramos is Associate Professor in the Business Department at the Autonomous University of Barcelona. Her research focuses on the fields of technology strategy and innovation, collaborations, and international business. Her work has been published in different international journals, such as Academy of Management Perspectives, Journal of Engineering and Technology Management, Technovation and Journal of Management and Organization, among others.