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RESEARCH

# Learning from prior national and international collaborations and eco-innovation: the moderating role of alliance portfolio diversity

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**Abstract** Eco-innovations integrate complex and diverse knowledge sources. For this reason, firms engage in worldwide collaborations that promote learning from different partners that, in turn, promote environmental innovations. This study analyzes how the learning experience of previous collaborations at the national and international levels impacts the likelihood of eco-innovation development by small- and medium-sized enterprises (SMEs). This work also examines whether such linkages between prior collaboration experience and eco-innovation are influenced by alliance portfolio diversity (APD), which can broaden the number of knowledge sources but also increase coordination costs. The results of longitudinal analysis, based on a dataset of Spanish SMEs, suggest that the learning acquired from prior domestic openness is more useful for enhancing eco-innovation activities. Moreover, the results confirm the negative moderating role of APD, as SMEs with greater prior experience in national and international openness are more likely to eco-innovate than those with less prior experience, but these relationships weaken with increased diversity in collaboration portfolios.

**Plain English Summary** "Collaborate, but not for too long and with diverse partners at the same time!" The prior experience of SMEs in collaborations, especially national ones, helps them generate more eco-innovations. However, these effects weaken when partner diversity increases. This paper analyzes how SMEs learn from prior collaborations with national and international partners to promote eco-innovation by addressing the inherent benefits and challenges associated with the duration and continuity of such collaboration, as well as the diversity of partnership choices. SMEs, which are typically constrained by resources, engage in collaboration to learn how to develop complex eco-innovations, facing a trade-off between the length of the collaboration and the diversity of the partners with which they can cooperate. The main implication of our study is that SMEs' learning from prior national collaborations is more valuable for enhancing eco-innovation than their international experience. This finding can be explained by the fact that geographical proximity optimizes knowledge transfer and smooths coordination problems due to physical and cognitive proximity, thus helping SMEs augment social value through enhanced eco-innovation. Furthermore, SMEs need to consider that having an alliance portfolio that is too diverse, with partners of different types and from different locations,

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reduces the positive effects of learning from prior alliances and environmental innovation.

**Keywords** Learning from collaboration · National collaborations · International collaborations · Eco-innovation · Alliance portfolio diversity

**JEL Classfication** Q55 · O36 · O32

## 1 Introduction

Eco-innovation, i.e., the introduction of new goods, services, and processes that reduce the number of negative environmental effects in the natural environment and promote sustainability (Triguero et al., 2013; Bitencourt et al., 2020), has become a key strategy for small- and medium-sized enterprises (SMEs) to increase their legitimacy, capture new market opportunities, and gain a competitive advantage (Demirel & Danisman, 2019). However, eco-innovations build upon particularly novel and technically complex knowledge inputs compared to nonenvironmental inputs (Barbieri et al., 2020), which require considerable SME efforts; SMEs tend to have more limited resources in comparison to large firms (Fischer et al., 2021; Lange & Wagner, 2021; Parida et al., 2012). As a result, SMEs are increasing their openness to collaborate with national and international partners to obtain specialized new resources, complementary skills, and competencies (van Beers & Zand, 2014), which can induce eco-innovation activities, as these enterprises become more exposed to more demanding environmental demands from distinct stakeholders (Marco-Lajara et al., 2023).

Traditionally, the literature has explored how firms' engagement in collaborations with diverse types of partners (e.g., customers, suppliers, and universities) affects eco-innovative performance (Acebo et al., 2021; De Marchi, 2012; Kobarg et al., 2020), largely supporting positive results. However, to date, it remains unclear how the learning experience from prior collaborations, which emerges after engaging in alliances over time (Wang et al., 2022), impacts environmentally friendly innovative outcomes in SMEs. From the lens of organizational learning theory (OLT) (Huber, 1991), in the context of interorganizational collaborations (Lavie & Miller, 2008), past experience in collaboration activities can improve SMEs' managerial capabilities, smooth coordination problems, and favor the absorption of green knowledge and technologies that SMEs may capitalize on to exploit eco-innovative opportunities due to their greater flexibility compared to large firms. However, it is also certain that environmental innovations usually involve novel discoveries and new technological trajectories, and thus, the learning acquired from past collaboration experience may not be applicable and may make firms rely on past routines and fall into competency traps, decreasing their chances of pursuing eco-innovations, which are by nature riskier and more uncertain (Leyva-de la Hiz & Bolívar-Ramos, 2022). Thus, this unresolved tension persists.

Furthermore, we cannot ignore that currently, the interorganizational collaborations in which SMEs participate over time and from which they learn are increasingly crossing national borders (Benhayoun et al., 2020). As a result, partners from different countries are brought together, pooling rich and varied resources and developing unique settings for knowledge acquisition and exploitation (Lavie & Miller, 2008; van Beers & Zand, 2014). Thus, in this study, and moving a step forward, we link OLT in interorganizational collaborations and the geography of networks (Hsieh et al., 2018) to examine how prior learning experience from collaborations at two contextual levels, namely, national (with partners from the same country) and international (with foreign actors), affects SMEs' likelihood of eco-innovation. As the geography of innovation underlines, this distinction is critical because it can alter how knowledge is absorbed as a context-specific resource (Audretsch & Belitski, 2023a; Jaffe et al., 1993). In fact, the effectiveness of learning is affected by the type of interactions, the way in which communication takes place, and the trust between the partners involved, which tends to be more reduced as geographical distance increases (Delgado-Marquez et al., 2018; Wagner et al., 2014). Thus, it is reasonable to expect that through a history of prior national and international collaborations, SMEs will acquire different learning experiences over time that, in turn, may distinctly affect their eco-innovation results.

In addition to previous arguments, there are certain aspects that may alter the relationships among previous instances of collaboration experience, both at the national and international level, and the likelihood of eco-innovation in SMEs. The literature

has widely acknowledged that the greater the diversity in the alliance portfolio is—i.e., "a firm's set of concurrent technology alliances" (Estrada & Zhou, 2021; p. 980)—in its functional and geographic dimensions (Delgado-Marquez et al., 2018), the richer the learning opportunities for firms (Srinivasan et al., 2021; van Beers & Zand, 2014). However, a portfolio of collaborations that is too complex can provide diminishing returns over time due to incompatibilities, redundancy, and coordination problems (Kobarg et al., 2019), which may be particularly relevant for SMEs. Hence, this study addresses the negative moderating role of alliance portfolio diversity (APD) as a factor that can weaken the positive effect of prior national and international collaboration experiences on eco-innovation when its complexity is too high.

Following the previous discussion, this study explores two research questions: how does the learning experience from prior national and international collaborations affect the likelihood of SMEs eco-innovating? Do these relationships vary depending on APD? To answer these questions, we carry out an empirical analysis based on a sample of 4488 manufacturing SMEs in Spain, analyzed over the period 2010–2016. The results of the study suggest that SMEs with prior experience in collaborations at the national level are more likely to eco-innovate, which can be explained by the fact that domestic collaborations not only may be more favorable for SMEs in terms of increasing their alliance management capabilities and absorbing the valuable knowledge local partners provide over time due to their geographic proximity, language, and cultural similarities (Santamaría et al., 2021) but also provide an appropriate setting for increasing trust and lowering collaborative costs (De Massis et al., 2018). This, in turn, helps them to understand the complex market, technological, and legal requirements of environmental innovation and to approach it in a more successful way (Horbach, 2008), as SMEs can learn from partners that share common mental schemes and similar cultural and institutional backgrounds (Balland et al., 2015). Furthermore, our results indicate that although prior collaboration experience in national and international alliances may induce positive results in eco-innovation outcomes, these learning effects are reduced by SMEs' APD, which exerts a negative moderating effect as it (i.e., diversity in functional partners and geographic locations) increases.

By filling these research gaps, first, this study contributes to the literature on open innovation and learning in interorganizational alliances (Hsieh et al., 2018; Lavie & Miller, 2008), providing novel insights into eco-innovation dynamics. This work not only acknowledges the benefits of both perspectives in promoting innovation but also discusses their inherent limitations related to the duration and continuity of the collaboration (learning over time), as well as the diversity of partners' choices in the alliance portfolio. Moreover, our research contributes to the literature on the geography of collaboration networks (Audretsch & Belitski, 2023a; Balland et al., 2015) by addressing previous calls that highlight the need to understand how firms learn from prior collaboration experience at the national and international levels for innovative purposes (Hsieh et al., 2018; Kapetaniou & Lee, 2019; Zahoor & Al-Tabbaa, 2020), with a particular focus on eco-innovation in SMEs (Yan et al., 2022). Our findings reveal that SMEs, due to their limited resources and constraints, benefit more from focusing on learning from national collaborations, compared to international collaborations, in an immediate context, which is consistent with recent research in the geography of innovation literature (Belitski & Rejeb, 2022; De Massis et al., 2018). National collaborations are characterized by cognitive and geographical proximity, and they optimize knowledge transfer processes and leverage cost efficiencies for SMES, which, in turn, enhances the duration and efficacy of learning processes, ultimately augmenting social value through increased levels of eco-innovation. In addition, our results confirm that although prior learning from national and international collaborations may be key to providing greater knowledge sources to SMEs for eco-innovation, as well as access to spillovers (Audretsch & Belitski, 2020; Audretsch & Keilbach, 2005), collaborating over time with too many different partners in the alliance portfolio (in functional and geographical terms) leads to a "too much of a good thing" situation that increases coordination and monitoring costs, the degree of knowledge disclosure, and the level of risk of partners' misappropriation (Hottenrott & Lopes-Bento), in turn reducing the positive effects of learning from alliances and eco-innovation outcomes. Finally, our study addresses the role of the localization of knowledge for social change in SMEs. In doing so, this research considers small firms' high-level contribution to sustainable development, as well

as eco-innovations' influence in improving business, natural, and social needs.

In the next sections, we present the theoretical background and hypotheses of our study. Later, we describe the data, sample, and results obtained in the empirical analyses. Finally, we discuss some of the main conclusions of this research.

## 2 Theoretical background

Interorganizational collaborations act as learning channels for SMEs through which they can obtain access to partners' proprietary and managerial knowledge and organizational routines (Howard et al., 2016) while simultaneously reducing their internal resource constraints. The more SMEs engage in collaborations with external partners over time, the better their ability to identify and exploit information sources, which favors the development of strategic and digital competences (Audretsch et al., 2021). In this study, we adopt the lens of the OLT and the knowledge-based view in collaboration networks (Hsieh et al., 2018), which posit that firms that continuously engage in alliances and thus acquire experience in collaborations can benefit from superior performance owing to the creation of intangible resources and novel knowledge (Grant, 1996). Notably, this engagement in external knowledge sourcing may have a higher and more immediate impact on supporting the development of total knowledge assets as a result of the higher codification and maturity of the knowledge available in the market (Denicolai et al., 2016). This situation may be especially relevant for promoting the development of environmental innovations, which usually require more external knowledge sources than nonenvironmental innovations (Acebo et al., 2021).

As the recombinant view of innovation points out, both external knowledge (e.g., from collaborations and spillovers) and internal knowledge (e.g., research and development (R&D) and learning) are complementary in producing innovative outcomes (Audretsch & Belitski, 2023b). In the case of eco-innovations, this complementarity is critical due to their multidimensional nature, which requires SMEs to obtain knowledge from distinct domains and sources to understand the legal and technological complexities embedded by environmental innovations, usually higher than that of other technological innovations (Bolívar-Ramos, 2023). The more complex tasks are, the more important in-depth learning and communication with partners, which in turn can enhance the limits to innovation (Saura et al., 2023), as described below.

Eco-innovations usually demand radical changes and new discoveries due to their novel nature, which departs from current technological trajectories to address environmental problems (Barbieri et al., 2020; De Marchi, 2012). In this sense, learning from prior alliances also poses some challenges that should not be ignored because success in the process is conditioned by firms' absorptive capacity, that is, their ability to acquire, use, and exploit external knowledge sources (Cohen & Levinthal, 1990; Lee et al.,; 2017; Zahra & George, 2002), which is usually more limited in small firms. Moreover, past experience in collaborations can also originate inertia and learning rigidities that preclude novel combinations (Lane & Lubatkin, 1998). Furthermore, repeated, deep interactions that promote learning also entail certain risks for SMEs, as they generate unintended knowledge leakages, creating conditions in which competitors can imitate the firm's products (Mariani & Belitski, 2022). This situation is especially risky when developing eco-innovations that require the exploration of novel domains to reduce negative environmental impacts and therefore require considerable innovative efforts and investments in an uncertain context (Leyva-de la Hiz & Bolívar-Ramos, 2022).

To provide a more fine-grained explanation of how learning from collaborations affects the development of eco-innovative outcomes, we should not ignore that SMEs learn from partners that are quite diverse in technological and geographic (national or international) origins (Phene et al., 2006; van Beers & Zand, 2014; Zahoor & Al-Tabbaa, 2020). Addressing this topic under the lens of the geography of network literature (Audretsch & Belitski, 2023a; Balland et al., 2015; Hsieh et al., 2018), this research aims to elucidate an unresolved tension in terms of the role of localization economies versus global networks in innovation (Audretsch & Belitski, 2020; Hervás-Oliver et al., 2018), which is still overlooked in the context of eco-innovation and SMEs. As Kafouros et al. (2020) point out, we have a limited understanding of how prolonged experience with either domestic or foreign partners affects a firm's innovative outcomes—in this case, eco-innovation. In a similar

vein, Kapetaniou and Lee (2019, p. 261) recently recall that "any potential innovation outcome depends on the spatial constraints on openness," pointing out that this topic has been largely understudied in the literature for SMEs. Furthermore, as Audretsch and Belitki (2023a, p. 102519) indicate, "cost−benefit analyses of collaborations for innovation are not well developed in organizational and open innovation theories," which provides an opportunity through which to further explore this research topic by concretely addressing how learning from experience in open innovation activities at the national and international levels affects the development of eco-innovations in SMEs. On the one hand, the rationale for firms' engagement in international alliances is based on their need to gain complementary knowledge and specialized technologies not available in the national context (Hsieh et al., 2018). However, the potential benefits from these diverse geographic networks may be consumed by partnerships that include cognitively distant partners, as this can produce communication problems and conflicts (Audretsch & Belitski, 2023b; Delgado-Marquez et al., 2018). Thus, since there is an ongoing debate on this topic, we aim to shed some light on it by contributing to the SME and environmental innovation literature, given the role played by these firms in society and the economy, aligning with sustainable practices to increase competitive advantage, providing employment and green opportunities to grow, and promoting the well-being of countries while responding to eco-friendly demands (Yan et al., 2022).

### 2.1 Relationship between prior experience in national and international collaborations and eco-innovation in SMEs

The geography of innovation literature points out that engagement in local collaborations over time, within close geographical proximity, enhances tacit knowledge diffusion and knowledge spillovers (Audretsch & Belitski, 2023a; Hervás-Oliver et al., 2018), as well as face-to-face interactions and social capital (Belitski & Rejeb, 2022). Thus, past research suggests that as SMEs accumulate experience in collaborating with local partners, the effectiveness of learning from openness increases due to greater knowledge flows between firms, the development over time of refined routines for collaboration, and increased trust, which nurture innovation activities (Messeni-Petruzelli, 2011; Zhang et al., 2022). Along these lines, Belitski and Rejeb (2022) recently found that family firms gain more from collaborations with their customers when they are located in domestic markets than in international markets. As an example of domestic collaborations, in Germany, the "Eco Innovation Alliance" unites over 60 start-ups and innovative companies from the green economy to promote knowledge exchange among firms, policy-makers, and other stakeholders. These collaborations aim to overcome regulatory hurdles and initiate R&D projects to create new opportunities for sustainable innovation (Eco-innovation Alliance, 2024). In this context, companies such as Siemens provide expertise and technological solutions so that startups can learn to create and develop scalable and eco-friendly innovations with greater ease.

Eco-innovations, by nature, are usually particularly novel and complex, embed knowledge inputs coming from distinct domains, and result in new radical technological outcomes (Barbieri et al., 2020). Under these circumstances, to be able to develop complex environmental innovations, SMEs require high levels of shared information, reciprocity, and mutual trust that increase social embeddedness, rich communications, and interactive learning, which are often best achieved when small firms have engaged in domestic alliances (Audretsch & Belitski, 2023a). Given that geographical proximity to partners and previous history in managing collaborations improve shared practices, lead to better understanding, lower the costs of coordination and control, and help firms manage ambiguous situations in an easier manner, the benefits from the experience from prior collaborations are likely to be higher (Sampson, 2005), which in turn may increase SMEs' eco-innovative performance.

As Donbesuur et al. (2021) point out, collaboration experience generates "environmental in-learning" that includes vicarious learning—imitating other firms' successful practices—and the transfer of environmental knowledge from continuous interactions among partners. This, in turn, constitutes a critical mechanism through which postformation alliance capabilities (e.g., interorganizational communication and coordination) positively impact SMEs' eco-innovation. In fact, when SMEs accumulate experience from prior domestic collaborations, they may be better positioned to identify

and assimilate partners' relevant knowledge (and key technological inputs) while simultaneously developing new capabilities that also help reduce their exposure to uncertainties by exploiting the resources and competences developed by others (Zahoor & Al-Tabbaa, 2020). The reason for this is that in the national context, SMEs have the opportunity to learn over time from partners that share cultural backgrounds and cognitive styles, which increases the chances of successfully innovating (Delgado-Márquez et al., 2018; Ye & Crispeels, 2021), in this case, with a green purpose.

However, the experience acquired by SMEs from collaborating with domestic partners over time may preclude exploration and experimentation in new markets and domains (e.g., with more advanced green strategies), as it usually increases expertise in the existing knowledge base (Sheng & Chien, 2016). This, in turn, may be detrimental for the development of eco-innovations that build upon diverse novel knowledge inputs and require long-term, risky, and uncertain exploration processes that move a step further from the exploitation of well-known technologies (Ghisetti et al., 2015). In fact, participating in local networks can reduce the scope for learning, as such a situation may lead to a lock-in (Audretsch & Belitski, 2023b; Delgado-Márquez et al., 2018) that deters innovation. As the learning obtained from prior domestic collaborations is restricted to "local search" (Rosenkopf & Almeida, 2003), it could also lead to inertia, path dependency, and greater difficulties in adapting to new market changes and trends (Dosi, 1988; Nelson & Winter, 1973; Wagner et al., 2014), including environmental trends, thereby trapping SMEs in the current trajectories and reducing the number of opportunities for eco-innovation. However, it is still plausible that due to their greater flexibility and more limited resources, compared to large firms (Fischer et al., 2021), SMEs may be willing to learn from local partners, which facilitates knowledge absorption and exploitation in a close geographical area (Zahoor & Al-Tabbaa, 2020), with the aim of developing and exploiting nascent environmental technologies with greater potential, especially for profitability (Leyva-de la Hiz & Bolívar-Ramos, 2022).

In light of previous arguments, we contend that the higher SMEs' level of prior collaborative experience in a domestic context is, the greater their effectiveness in the exchange of ideas and efficacy of learning processes for eco-innovation, as firms will be more willing to share and gain knowledge from partners that have the same cultural and institutional frameworks (e.g., environmental regulations and concerns), and this proximity will lower the number of misappropriations and misunderstandings and facilitate the achievement of a common goal (Ye & Crispeels, 2021). Thus,

> *H1: SMEs with greater prior experience in national collaborations are more likely to eco-innovate.*

Eco-innovation development is a complex process that challenges firms' traditional products, demands new resources from different fields, prevails in rapidly changing natural environment contexts, and pushes firms, including SMEs, to engage in external collaborations with stakeholders from different geographical and institutional origins to compensate for the lack of internal knowledge, technologies, and expertise (Watson et al., 2018). Under these circumstances, international experience provides a learning opportunity that helps introduce eco-innovations to address new business opportunities related to markets committed to sustainable consumption (Marco-Lajara et al., 2023). The reason for this is that a history of collaborations with foreign partners offers heterogeneous, rich, and varied knowledge sources from distinct partners but also different geographies (Kafouros et al., 2020; Wagner & Zidorn, 2017). To illustrate, Circular Computing, an SME headquartered in UK, engaged in an international alliance with Atos, a global leader in digital transformation, with the purpose of expanding the portfolio of carbon–neutral remanufactured laptops to supply their clients with the most sustainable laptops in the world and, at the same time, deliver all their technology needs (Atos, 2021). This collaboration exemplifies how SMEs' international alliances can be a valuable mechanism to exchange specialized technical knowledge, beyond their organizational and national boundaries. These partnerships foster the co-creation of eco-innovative solutions and promote sustainable practices worldwide, which might not be possible within a domestic context alone.

We should not ignore that as SMEs learn from prior international collaborations for eco-innovation, the opportunities to strengthen social relationships

over time may be more limited due to the lack of physical proximity, reduced trust, and less frequent knowledge-intensive exchanges (Boschma, 2005; Capaldo & Messeni-Petruzzelli, 2014; Hsieh et al., 2018). Overall, the potential benefits from diverse networks may be consumed by partnerships that include cognitively distant partners, as this can produce communication problems and conflicts (Audretsch & Belitski, 2023a; Delgado-Marquez et al., 2018). Furthermore, knowledge spillovers are geographically bounded and closely located in spatial proximity to the knowledge source (Audretsch & Keilbach, 2005), which means that they cannot be easily replicated in other places (Audretsch & Belitski, 2023a, b). Although mixed evidence persists, we suggest that SMEs' prior experience in international collaborations could smooth some of the issues to the detriment of green innovative activities, as discussed below.

International experience from repeated foreign collaborations can have a positive influence on SMEs' eco-innovations, as they become exposed to more demanding environmental pressures and to different countries' environmental knowledge and regulations, which induces new eco-innovative possibilities (Aragón-Correa et al., 2020; Marco-Lajara et al., 2023). Scholars have long recognized that firms that launch innovations with higher degrees of novelty, as occurs with eco-innovations, tend to use more varied, richer, and wider ranges of external knowledge sources, which usually cross national borders (Kafouros et al., 2020; Kapetaniou & Lee, 2019). Hsieh et al. (2018) show that the advantages of tapping into foreign countries are stronger when geographical diversity increases, which shows that "competency traps" or knowledge inertia in learning processes from collaborations do not arise if the same interorganizational linkages are formed in distinct countries.

As SMEs learn from collaborating with their foreign partners over time, not only do they gain valuable inputs and complementary resources for eco-innovation that may be fragmented and geographically dispersed (Lavie & Miller, 2008), but they also internalize best practices, develop codified routines, and improve their alliance management capability (Fischer et al., 2021; Rothaermel & Deeds, 2006). More accessible ways to communicate with strategic partners who are globally dispersed, owing to new technologies, along with a common scientific language, support the idea that the international collaborative experience can be a valuable asset for eco-innovative activities. In SMEs, the learning acquired from international collaborations can boost eco-innovative practices, since the international experience has been found to have a positive effect on proactive environmental strategies, the accumulation of green knowledge, and the development of novel eco-friendly products to comply with the environmental regulations of foreign markets (Marco-Lajara et al., 2023). Furthermore, as a result of increased social pressures regarding environmental sustainability, SMEs may also learn more advanced environmental practices and improve their legitimacy to eco-innovate owing to their prior experience in international collaborations with partners that may help them overcome their liability of origin when coming from home countries with weak institutional regimes (Leyva-de la Hiz et al., 2019a, b).

Currently, SMEs can overcome some of their resource limitations by accessing web-based platforms, which offer an affordable way to collaborate with widely dispersed partners and help reduce social, cultural, and geographic barriers (Audretsch et al., 2021). Based on the above factors, we contend that SMEs' prior experience in international openness may be key for increasing the likelihood of developing eco-innovative products, given the richer access to technologies, scientific ideas, and knowledge provided by foreign collaborations over time (Hsie et al., 2018) but also due to a better understanding of customers' green demands and environmental regulations (Aragón-Correa et al., 2020). Thus, in a context characterized by higher uncertainty, extensive prior experience in international collaborations will allow SMEs to gain insights into how to identify the most effective processes to exchange technologies with their partners, manage complex situations, and disseminate the knowledge gained through alliances (Sampson, 2005; Zahoor & Al-Tabbaa, 2020). Overall, international experience can help SMEs promote eco-innovation due to it providing them with a better understanding of green competitive dynamics, foreign customers' needs, technological developments, and legislative regulation (Marco-Lajara et al., 2023). Thus,

*H2: SMEs with greater prior experience in international collaborations are more likely to eco-innovate.*

### 2.2 Moderating role of alliance portfolio diversity in the relationship between prior experience in national and international collaborations and eco-innovation in SMEs

Whereas we propose that prior experience in collaborations (both national and international) is positive for generating eco-innovations in the firm, in this study, we move a step further and analyze the role of APD in this relationship, which captures the interorganizational knowledge flows with which the firm experiments using a variety of actors, such as customers, suppliers, universities, and competitors, from different locations (Martínez-Noya & García Canal, 2021).

The analysis of APD and its effect on firm innovation have attracted great scholarly attention but has not reached a consensus (Wuyts & Dutta, 2014). Through alliances with several types of partners, firms can overcome the limitations of their internal R&D and gain knowledge owing to their absorptive capacity (Cohen & Levinthal, 1990; Lee, et al., 2017). Firms can access unique resources, recombine them, and generate new and valuable innovations (Asgari et al., 2017; Capaldo, 2007; Lange & Wagner, 2021). In this regard, some authors (e.g., Martínez-Noya & García-Canal, 2021; Srivastava & Gnyawali, 2011) state that firms need to broaden their alliance portfolio since "a single partner cannot provide all the required inputs" to generate innovations (Marhold et al., 2017, p. 2). Having fewer partners may generate knowledge overlap and offer limited solutions to complex problems that may be posed by environmental innovations (e.g., Barbieri et al., 2020). To illustrate, the work from Aragón-Correa and colleagues (Aragón-Correa et al., 2020, p. 339) about firms' environmental strategies calls for examining "more than a single environmental pressure at a given time," hence remarking on the complexity of considering environmental factors. Likewise, environmental innovations exhibit higher levels of uncertainty than do nonenvironmental innovations (e.g., Leyva-de la Hiz, 2019), thus generating broader scenario planning that requires ideas from diverse partners (Martínez-Noya & García-Canal, 2021). Given that SMEs possess fewer resources than large corporations (Kapetaniou & Lee, 2019; Wagner & Zidorn, 2017), accessing diverse knowledge externally may overcome their limited capabilities for generating relevant knowledge internally. However, this access could be a double-edged sword, as the more diverse the alliance portfolio is, the higher its associated costs. Having a broader alliance portfolio implies a larger cognitive distance (Delgado-Márquez et al., 2018) and increases the search cost for finding the most adequate partners, i.e., those from which firms can effectively use their absorptive capacity (e.g., Gupta et al., 2020). Even if such partners are found, a diverse portfolio increases the potential for conflicts and coordination costs. Conflicts may arise because the sharing of valuable knowledge can spur trust issues, as partners may eventually become direct competitors and misappropriate some of the rents the firm could fully enjoy otherwise. For instance, Joshi and Nerkar's (2011) study of patent pools showed that when firms from the same industry worked together to generate a technological standard, they avoided sharing their most significant patents, and their contribution to the pool was very limited, as higher-level knowledge development would result in lower future rents.

In addition to these conflicts, having a more diverse alliance portfolio hinders the coordination of the learning process, as firms need to manage a wider variety of knowledge flows; this is an issue that is particularly relevant in the environmental arena. In this regard, Ghisetti and colleagues (Ghisetti et al., 2015, p. 1090) studied the effect of knowledge sourcing over environmental innovations, reaching to the conclusion that environmental innovations can be generated "only when eco-innovators do not face congestion problems from an excessive array of external knowledge sources."

Social learning theory (Bandura, 1997; 1999; Wenger, 1999), a subset of OLT (Huber, 1991) that deepens the understanding of the relationships among participants who learn from each other, offers a four-step model that explains this learning process, namely, "attention," "retention," "reproduction," and "motivation." The first step, i.e., *attention*, is key since to learn from others, we need to pay close attention to what they are doing. This situation is the first difficulty associated with possessing a diverse set of partners. This variety generates a problem of attention location, i.e., it becomes more difficult to distinguish between relevant and nonrelevant knowledge (Estrada & Zhou, 2021) since a given piece of knowledge may be extremely relevant for firm A but irrelevant for firm B. This difficulty increases as knowledge diversity increases, thus generating a problem of diminishing marginal returns.

As Kobarg et al., (2019; p. 2) state, "[t]he marginal value added of additional assimilated knowledge, further learning, or increased resource sharing decreases with additional increments of [knowledge] breadth." In the case of environmental innovations, given their complex nature, the *attention* issue tends to be greater than for non-environmental innovations (Ghisetti et al., 2015). The second step of the learning process described by social learning theory—called "retention"—may also be negatively affected by a highly diverse portfolio. Most companies do not possess sufficient capabilities for handling a high degree of variety of bodies of knowledge (Lee et al., 2017); thus, the more diverse the alliance portfolio is, the greater its difficulty in effectively absorbing knowledge. Whereas this condition may be applied to all types of firms, it becomes more salient in the case of SMEs, as they have limited resources. As a result, SMEs cannot pay full attention to a diverse set of knowledge that may (or may not) be useful for them. The third step of the learning process—called "reproduction"—depends not only on the firm's absorptive capacity (Cohen & Levinthal, 1990) but also on its resources, and in this case, again, SMEs are at a clear disadvantage compared to large corporations, as the latter may commit significant resources to apply, i.e., replicate, what it has learned from its counterparts. Finally, the fourth step of the learning process—called "motivation"—refers to the intrinsic reasons for applying the knowledge acquired (Muro & Jeffrey, 2008). In this case, whereas we consider that SMEs may not be in a disadvantageous position compared to large companies (in fact, the situation may be the opposite, as SMEs may be more motivated to apply external knowledge due to their scarcity of internal resources), as we stated above, social learning theorists have established the learning process as a step-by-step model; then, if SMEs face difficulties throughout step 1 (*attention*), step 2 (*retention*), and step 3 (*reproduction*), then they may fail to arrive at the last step of the process (*motivation*).

Therefore, given the reasons presented here, and although we acknowledge a relevant number of studies that both advocate and question the diversity of the alliance portfolio, we consider that the disadvantages exceed the advantages, particularly in the case of SMEs, as they suffer from limited capabilities that preclude them from overcoming the abovementioned drawbacks.

In the case of collaborating with partners from the same country, firms are more physically and mentally close (La Porta et al., 1998), hence making knowledge exchange more useful and facilitating firms' absorptive capacity. According to social learning theorists (e.g., Bandura, 1997; 1999; Wenger, 1999), this situation would improve the *attention* and *retention* steps of the social learning process. In this vein, some authors (e.g., Gupta et al., 2020) remark on the importance of societal cultural frameworks, where informal links exert an important influence on firms' relations, which may reduce some of the aforementioned disadvantages of building broader alliance portfolios. In this regard, Hsieh et al., (2018; p. 654) suggest that "coordination challenges and the risk of misappropriation" are lower when a firm collaborates within its national borders. However, having a lower level of challenges does not mean that such challenges are irrelevant for the company, particularly in the case of small firms. As we stated above, SMEs do not possess the resources to completely evaluate every single knowledge flow they receive; therefore, the wider the alliance portfolio is, even in the national context, the greater the problem of attention location (Estrada & Zhou, 2021). In addition, environmental innovations are more complex than nonenvironmental innovations (Barbieri et al., 2020; Leyva-de la Hiz, 2019), hence requiring more profound knowledge. In this vein, Ghisetti et al. (2015; p. 1,083) argue that developing environmental innovations may lead to decreasing returns because they "may impose greater stress on the attention resources of the firm." This difficulty would also hinder the firm's ability to *reproduce* (step 3 of the social learning process) what its partners are doing. Therefore, we consider that in the case of SMEs, a greater degree of APD negatively moderates the positive relationship between learning from prior national collaborations and eco-innovation. Thus,

> H3: The positive relation between prior experience in national collaborations and eco-innovation weakens when SMEs' APD increases.

In regard to collaborating with a diverse set of partners from other countries, some of the advantages of the knowledge flow within the same country may disappear. In an international context, companies have to address different institutional settings, which

can hinder communication among partners that are already cognitively distant. This hindering of communication has a negative effect on a firm's *attention* capacity but is particularly adverse to its *retention* capacity (steps 1 and 2 of the social learning process, respectively) (Bandura, 1997; 1999). In this regard, several authors have acknowledged the importance of national institutions in companies' strategies and behaviors (e.g., Ahmadova, et al., 2022; Hoffman, 1999), even within globalized multinational enterprises (MNEs). For example, Ahmadova et al.'s (2022) analysis of MNEs from more than 40 countries showed that their green performance was affected by the national context in which these companies belong, despite operating across many countries. In addition, collaborating with overseas partners may spur trust issues, as "trust in collaborations is perceived and is developed differently between cultures" (Kafouros et al., 2020; p. 119,757). In other words, the geographical diversity of a firm's partners adds to their already existing functional diversity, hence increasing the cognitive distance from the focal firm. That is, cognitive distance comes from a double source, i.e., geographical and functional breadth.

In this vein, although more distinct partners extend the firm's knowledge base, generate new routines, provide new solutions, and allow for the development of new ideas (Huber, 1991; Lavie & Miller, 2008), it also increases its related managing costs (Delgado-Márquez et al., 2018), which may be particularly detrimental in the case of SMEs. This type of firm still lacks the needed comprehensive set of resources to take advantage of all this knowledge input. That is, SMEs may be exposed to many and too different ideas from different partners that are embedded in different institutional contexts, and thus, it may become extremely difficult for these firms to distinguish which ideas are most relevant for the focal company. SMEs may be overwhelmed with an unapproachable amount of information that needs to be analyzed in a short period of time. To this situation, we have to add the already mentioned complexity of environmental innovations, as they require a greater amount of time and resources to be developed (Carfora et al., 2022; Przychodzen, et al., 2020). A good example of this could be the current energy crisis, which has been exacerbated by the Ukraine-Russia conflict. Before the dramatic increase in energy prices, the European Union (EU) had a clear route map toward the progressive dismantling of nuclear power plants in favor of renewable resources, such as the €118 billion allocated in 2016 for this purpose (Reuters, 2016). However, environmental technologies have not been developed along the expected path, thus driving the EU to make a "U-turn" and embrace nuclear energy as a solution to the current problem (Time, 2022). This uncertainty of environmental innovations (e.g., expected vs. current progress of green energy) hinders SMEs' decision-making process and shows how difficult it is to *reproduce* (step 3 of the social learning process) the intended advancements.

To sum up, we consider that SMEs should not pursue a wide diverse portfolio of partners (in terms of functional and geographical breadth) for developing environmental innovations. In this case, accessing information sources that are too varied for SMEs generates diminishing returns. Therefore, we consider that in the case of SMEs, wider APD negatively moderates the positive relationship between prior experience in international collaborations and eco-innovation. Thus,

> H4: The positive relation between prior experience in international collaborations and eco-innovation weakens when SMEs' APD increases.

## 3 Method

### 3.1 Data and sample

To test our hypotheses and develop our empirical analysis, we use panel data from Spanish technology-based firms. These data are obtained from the Technological Innovation Panel ("PITEC"), which is collected yearly by the National Statistics Institute of Spain ("INE"), with the support of the Spanish Foundation for Science and Technology ("FECYT") and the Foundation for Technological Innovation ("COTEC"), following European standards and the Community Innovation Survey. This database is useful for studying firm innovation, as its questionnaire includes multiple variables of interest, such as collaborations with different partners/geographies over a period of time and R&D activities, and provides information on eco-innovative objectives in technological innovation. As a consequence, several researchers have used this database as an appropriate

instrument for the analysis of collaborations and environmental innovation (e.g., Acebo et al., 2021; Arranz et al., 2020).

After restricting the sample to SMEs, the focus of our study, in our research, we work with a sample of 4488 firms observed over the period 2010–2016. This sample results after considering manufacturing technology-based SMEs—a common approach in past research, given that service firms present differences in innovative activities and cooperation patterns (De Marchi, 2012)—without missing values in the variables relevant to the study. Finally, 2010 is taken as the year of reference because changes in the nature of the questionnaire condition the possibility of including some of the variables of interest in previous years.

## 3.2 Variables and measures

### *3.2.1 Dependent variable: eco-innovation*

**Eco-innovation** In this study, we measure eco-innovation as a binary variable that takes a value of 1 when the firm reports that in the innovation activities carried out over the last three years, innovations that reduced environmental impact were important or at a high level and 0 otherwise. We need to note that a lag of one year between the dependent and independent variables is considered to improve causality (Kafouros et al., 2020). This measure is based on De Marchi's (2012) study, which uses the PITEC criterion to classify firms introducing environmental innovations versus those that do not. The main advantage is that the use of a binary variable considering the objectives presented in this study allows for comparisons with emerging evidence in the literature (De Marchi, 2012; Martínez-Ros & Kunapatarawong, 2019; Rhaiem & Doloreux, 2022).

### *3.2.2 Independent and moderator variables*

**Prior experience in national collaborations** Capturing the learning experience by counting the total number of years in which a firm has collaborated with other partners is a proxy that is well established in the literature (e.g., Estrada & Dong, 2020; Nieto & Santamaría, 2007). Thus, following previous research (Kafouros et al., 2020), this variable reflects the learning the firm has performed as a result of its collaborations with other domestic partners over a number of years, measured by the number of years in which the firm had participated in collaborations with other partners located in Spain over the period 2010–2016. Partners include companies from the same group, customers, suppliers, competitors, R&D institutes, universities, technology centers, and public research institutions.

**Prior experience in international collaborations** In line with the abovementioned logic, this variable measures the number of years in which the firm had participated in collaborations with other partners located in other countries over the period 2010–2016. Thus, the variable reflects the learning the firm has performed over time from collaborations with foreign counterparts, including companies from the same group, customers, suppliers, competitors, R&D institutes, universities, technology centers, and public research institutions.

### *3.2.3 Moderator*

**Alliance portfolio diversity (APD)** APD simultaneously considers the functional and geographical diversity of the firm's collaboration portfolio. Based on recent research, we adopt the Martínez-Noya and García Canal (2021) approach to measure this variable. In the questionnaire, firms are asked to report each year with whom of the following partners they actively cooperated for technological innovation: other firms from the same group, suppliers, clients, competitors, commercial labs, universities, and technological research centers. Furthermore, for each one of the previous collaborators, firms note their precise geographic location, considering their country of origin (i.e., Spain), other EU countries, the USA, China or India, and other countries. Taking all this information together, we compute "APD" as the total count of the different partner-geographic location combinations that SMEs had for a given year.

### *3.2.4 Control variables*

In addition to firm size, as a key organizational characteristic, the analyses consider a set of additional variables that are likely to affect environmental innovation outcomes and that refer to technology push, market pull, and policy factors (Horbach, 2008; Triguero et al., 2013). Thus, we control for internal and external R&D (Rhaiem & Doloreux, 2022),

patents, technological infrastructure, investing in staff training for innovation, and the firm's objective to innovate to penetrate a new market to increase market share, the degree of market uncertainty, and the amount of funds from public administrations (Fernández et al., 2021). Finally, industry and year control variables are also considered in the models.

First, firm size is measured by the logarithm of the total number of employees. In addition, internal R&D expenditures are measured by the logarithm of the R&D investments undertaken in-house, while external R&D expenditures are measured similarly but considering external sources. Then, patents are measured by the total number of patent applications, in logarithmic form. Technological infrastructure reflects expenditures in the acquisition of machinery, equipment, advanced hardware, or software to introduce new products, in logarithmic form, whereas training expenditures consider investments in training staff for innovation activities, in logarithmic form. Apart from the above aspects, new market and market share are two binary variables that equal 1 if the firm's objective of innovation, with a high degree of importance, is to penetrate a new market or to increase its market share, respectively, and zero otherwise. Market uncertainty is another binary variable that reflects whether the market is dominated by established companies and uncertain demand, with a value of 1, and zero otherwise (Arranz et al., 2020). For policy factors, the variable public administration funding is assigned a value of 1 if the firm received any financial support from these institutions (at the European, national, regional, and/or local levels) and 0 otherwise (Fernández et al., 2021). Finally, year and industry dummies for different technology sectors, based on the National Classification of Economic Activities (CNAE) 2009 codes, are included in the models. Table 1 summarizes all the variables and their descriptions.

### 3.3 Empirical analyses

Table 2 contains the descriptive statistics and the correlation matrix. Consistent with our expectations, prior experience from national and international collaborations is positively and significantly correlated with eco-innovation. Overall, none of the correlations suggests that multicollinearity may be a problem, which is confirmed after computing variance inflation factors, ranging between 1.04 and 2.47 in this case, as the literature accepts those below five or even ten (O'brien, 2007).

We run our empirical longitudinal analyses with Stata 17. The methodology and the model used are conditioned by the nature of the dependent variable, "eco-innovation," which is a binary variable. Thus, we estimate random effects probit models, consistent with past research (Acebo et al., 2021). The random effects model is suitable in this case to solve the incidental parameter problem that occurs in binary data panel models (Croissant & Millo, 2018). Thus, in line with the study and hypotheses, the basic model equation can be represented as follows:

$$P(EI_{i,t}) = \alpha_1 + \beta_1 PENC_{i,t-1} + \beta_2 PEIC_{i,t-1} + \beta_3 APD_{i,t-1} + \beta_4 C_{i,t-1} + \varepsilon_{i,t-1}$$

Pr (EIi, $t$) denotes the probability of eco-innovation for firm $i$ at time $t$. PENC$i$,t-1 refers to prior experience in national collaborations, PEIC$i$,t-1 represents prior experience in international collaborations, and APD $i$,t-1 is the degree of APD. The vector C$i$,$t-1$ includes all the control variables, and $\varepsilon_{i,t-1}$ represents a standard error. Moreover, to take into account the moderating effect of APD, we add a set of interaction terms to the initial basic model:

$$Pr(EI_{i,t}) = \alpha_1 + \beta_1 PENC_{i,t-1} + \beta_2 PEIC_{i,t-1} + \beta_3 APD_{i,t-1} + \beta_4 PEC_{i,t-1} * APD_{i,t-1} + \beta_5 C_{i,t-1} + \varepsilon_{i,t-1}$$

where PEC corresponds to, alternatively, previous experience in national (PENC) or international (PEIC) collaborations. In sum, regarding the regressions, Model 1 presents the basic model with only the control and main independent variables. Next, to test for moderation effects, we introduce several interaction terms between previous experience in national/international collaboration and APD in Models 2, 3, and 4. In the analyses, all the variables are mean centered.

### 3.4 Results

Table 3 describes the results of the regression analyses, from the basic model to the complete models.

In line with the results reported in Model 1, firm size, internal and external R&D, patents, technological infrastructure, training, market share, new market, market uncertainty, and public funding have a positive and significant effect on eco-innovations ($p < 0.05$).

**Table 1** Variables and definitions

| Variable | Description |
|---|---|
| Dependent variable | |
| Eco-innovation | Binary variable = 1 when the firm reports that in the innovation activities carried out over the last three years, innovations that reduced environmental impact were important and 0 otherwise |
| Independent and moderator variables | |
| Prior experience in national collaborations | Number of years in which the firm had participated in collaborations with other partners located in Spain over the period 2010–2016 |
| Prior experience in international collaborations | Number of years in which the firm had participated in collaborations with other partners located in other countries over the period 2010–2016 |
| APD | Total number of different partner-geographic location combinations that SMEs had for a given year |
| Control variables | |
| Firm size | Total number of employees, in logarithmic form |
| Internal R&D | R&D expenditures in-house, in logarithmic form |
| External R&D | External R&D expenditure, in logarithmic form |
| Patents | Total number of patents, in logarithmic form |
| Technological infrastructure | Expenditures in the acquisition of machinery, equipment, advanced hardware or software to introduce new products |
| Training | Expenditures to train the staff for innovation activities, in logarithmic form |
| New market | Binary variable = 1 when the firm reports the high-level importance of the objective of entering a new market to innovate and 0 otherwise |
| Market share | Binary variable = 1 when the firm reports the high-level importance of the objective of increasing market share to innovate and 0 otherwise |
| Market uncertainty | Binary variable = 1 when the market is dominated by established companies and uncertain demand and 0 otherwise |
| Public funding | Binary variable = 1 if the firm had received any financial support from public institutions (at the European, national, regional or local level) and 0 otherwise |

While we expect positive signs for these coefficients in general terms, it is surprising that market uncertainty exerts a positive effect on environmental innovations. This finding may be explained because although SMEs operate in dynamic and uncertain environments, eco-innovations still present promising opportunities in the market to achieve a competitive advantage and succeed in this context. Furthermore, in Model 1, we observe that prior experience with national collaborations positively and significantly affects the likelihood of introducing eco-innovations ($\beta = 0.046$, $p < 0.001$), which supports hypothesis 1. In economic terms, an increase in one-unit (year) of experience in collaborations with national partners increases the probability to eco-innovate by 4.6 percent. However, although the coefficient for prior experience from international collaborations also has a positive effect on the likelihood of eco-innovating, this effect is not significant ($\beta = 0.020$). Thus, hypothesis 2 is not supported, suggesting that SMEs face fewer difficulties learning from closer partners (domestic) than from international partners for environmental innovation purposes. The reason for this may be that consistent with recent findings in the geography of collaboration studies, national collaborations promote innovation outcomes to a greater extent than international alliances (Belitski & Rejeb, 2022; Bolívar-Ramos, 2017; De Massis et al., 2018), as partners share cognitive and spatial proximities that enhance the degrees of transfer, absorption, and exploitation of relevant knowledge (Audretsch & Belitski, 2023c). Moreover, local alliances minimize coordination costs, enhance trust among partners, and improve the efficacy of learning processes for SMEs to understand the intrinsic complexities that lead to the development of eco-innovations.

Model 2, which tests the moderating role of APD on the relationship between prior experience with national collaborations and eco-innovation,

**Table 2** Descriptive statistics and correlations

| Variables | Mean | S.D | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) Eco-innovation | 0.411 | 0.492 | 1.000 | | | | | | | | | | | | | |
| (2) Firm size | 3.733 | 1.024 | 0.189* | 1.000 | | | | | | | | | | | | |
| (3) Internal R&D | 6.432 | 6.087 | 0.451* | 0.311* | 1.000 | | | | | | | | | | | |
| (4) External R&D | 2.454 | 4.613 | 0.248* | 0.211* | 0.415* | 1.000 | | | | | | | | | | |
| (5) Patents | 0.118 | 0.398 | 0.117* | 0.119* | 0.235* | 0.189* | 1.000 | | | | | | | | | |
| (6) Tech. infrastructure | 1.447 | 3.794 | 0.136* | 0.143* | 0.139* | 0.110* | 0.052* | 1.000 | | | | | | | | |
| (7) Training | 0.920 | 2.695 | 0.179* | 0.117* | 0.244* | 0.181* | 0.086* | 0.306* | 1.000 | | | | | | | |
| (8) Market share | 0.329 | 0.469 | 0.321* | 0.145* | 0.422* | 0.213* | 0.139* | 0.121* | 0.149* | 1.000 | | | | | | |
| (9) New market | 0.332 | 0.471 | 0.335* | 0.128* | 0.433* | 0.230* | 0.155* | 0.109* | 0.163* | 0.664* | 1.000 | | | | | |
| (10) Market uncertainty | 0.533 | 0.312 | 0.120* | −0.036* | 0.149* | 0.087* | 0.027* | 0.028* | 0.075* | 0.127* | 0.139* | 1.000 | | | | |
| (11) Public support | 0.278 | 0.448 | 0.255* | 0.180* | 0.471* | 0.403* | 0.175* | 0.138* | 0.171* | 0.232* | 0.267* | 0.097* | 1.000 | | | |
| (12) Prior exp. national collabs | 0.618 | 1.322 | 0.240* | 0.190* | 0.344* | 0.361* | 0.137* | 0.114* | 0.181* | 0.199* | 0.233* | 0.086* | 0.383* | 1.000 | | |
| (13) Prior exp. internat. collabs | 0.248 | 0.824 | 0.176* | 0.175* | 0.256* | 0.275* | 0.130* | 0.104* | 0.151* | 0.164* | 0.175* | 0.050* | 0.210* | 0.510* | 1.000 | |
| (14) APD | 0.779 | 1.815 | 0.240* | 0.203* | 0.358* | 0.392* | 0.191* | 0.134* | 0.209* | 0.216* | 0.242* | 0.084* | 0.369* | 0.651* | 0.654* | 1.000 |

shows that the interaction term is negative and significant ($\beta = -0.015$, $p < 0.01$). Therefore, as predicted, hypothesis 3 is supported. Finally, in Model 4, which tests the moderating effect of APD on the relationship between prior experience with international collaboration and environmental innovation, it is possible to verify that the interaction term is negative and significant ($\beta = -0.013$, $p < 0.1$). Consequently, hypothesis 4 is also supported. Finally, Model 4 reflects the full model, considering SMEs that possess prior experience in collaborations with national and international partners. Again, the results reveal the importance of the learning experience from previous domestic collaborations to increase the likelihood of eco-innovation, while bearing in mind that this relation becomes weaker when APD increases.

To test the robustness of our results, additional analyses are performed. To correct for potential sample selection bias, as noninnovative firms are excluded from the analysis (PITEC poses questions on eco-innovation objectives only to innovative firms), we carry out a robustness check through a heckprobit estimation based on the Heckman procedure to account for the binary nature of our dependent variable (e.g., as in Marzucchi & Montresor, 2017). We use the variable exports for the exclusion criteria in the outcome equation (the dependent variable is "eco-innovation") and introduce it in the selection equation (the dependent variable is "innovation"). The reason for this is that past research suggests that exports may not drive eco-innovation decisions (Acebo et al., 2021; Kobarg et al., 2020; Marzucchi & Montresor, 2017), whereas, in general and not specifically "green" terms, it has been demonstrated that being active in international markets positively affects the decision to innovate. Based on the results of the Wald test for independent equations (available upon request), we cannot reject the null hypothesis that these equations are independent (rho = 0). Thus, our analyses can be estimated with probit models as initially reported, which reinforces the support for our findings.

Further, to control for potential endogeneity between collaboration experience (national/international) and eco-innovation, an additional robustness check with instrumental variable regression can be helpful, despite the controversy about its appropriateness for studies based on CIS databases (Haus-Reve

**Table 3** Probit random effects models. Dependent variable: eco-innovation

| Variables | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Firm size | 0.289*** | 0.288*** | 0.288*** | 0.288*** |
| | (0.026) | (0.026) | (0.026) | (0.026) |
| Internal R&D | 0.082*** | 0.081*** | 0.081*** | 0.081*** |
| | (0.004) | (0.004) | (0.004) | (0.004) |
| External R&D | 0.017*** | 0.016*** | 0.016*** | 0.016*** |
| | (0.004) | (0.004) | (0.004) | (0.004) |
| Patents | 0.101** | 0.101** | 0.101** | 0.101** |
| | (0.043) | (0.043) | (0.043) | (0.043) |
| Technological infrastructure | 0.020*** | 0.020*** | 0.020*** | 0.020*** |
| | (0.004) | (0.004) | (0.004) | (0.004) |
| Training | 0.016*** | 0.016*** | 0.016*** | 0.016*** |
| | (0.006) | (0.006) | (0.006) | (0.006) |
| Market share | 0.260*** | 0.261*** | 0.261*** | 0.261*** |
| | (0.041) | (0.041) | (0.041) | (0.041) |
| New market | 0.284*** | 0.282*** | 0.282*** | 0.282*** |
| | (0.041) | (0.041) | (0.041) | (0.041) |
| Market uncertainty | 0.223*** | 0.224*** | 0.224*** | 0.224*** |
| | (0.056) | (0.056) | (0.056) | (0.056) |
| Public support | 0.125*** | 0.119*** | 0.122*** | 0.120*** |
| | (0.039) | (0.039) | (0.039) | (0.039) |
| Prior experience, national collaborations | 0.046*** | 0.061*** | 0.044*** | 0.062*** |
| | (0.016) | (0.017) | (0.016) | (0.018) |
| Prior experience, international collaborations | 0.020 | 0.042 | 0.060* | 0.041 |
| | (0.026) | (0.027) | (0.034) | (0.035) |
| APD | 0.028** | 0.041*** | 0.031** | 0.041*** |
| | (0.013) | (0.013) | (0.013) | (0.014) |
| Prior experience national collaborations*APD | | −0.015*** | | −0.016** |
| | | (0.005) | | (0.007) |
| Prior experience international collaborations*APD | | | −0.013* | 0.000 |
| | | | (0.007) | (0.009) |
| Industry | YES | YES | YES | YES |
| Year | YES | YES | YES | YEs |
| Constant | −1.246*** | −1.209*** | −1.213*** | −1.210*** |
| | (0.132) | (0.133) | (0.134) | (0.134) |
| Observations | 20,143 | 20,143 | 20,143 | 20,143 |
| Number of ident | 4488 | 4488 | 4488 | 4488 |

Standard errors are in parentheses. ***$p<0.01$, **$p<0.05$, and *$p<0.1$. Note: coefficients are marginal effects (dy/dx)

et al., 2019). In this additional test, we considered a two-stage analysis (Wooldridge, 2009). Based on previous relevant literature on the topic, the average level of collaboration in the industry and belonging to a group were selected as instrumental variables (IVs) (e.g. Audretsch & Belitski, 2020). We verified that both the average level of collaboration in the industry and group are valid and suitable instruments (IVs) and confirmed they positively and significantly ($p<0.05$) affect the potential endogenous variables (national/international collaborations) in the first stage equation where national and international collaboration experience is predicted using the IVs. Then, in the second-stage equation, the Wald test of exogeneity did not

allow us to reject the null hypothesis of exogeneity of the instrumented variable (i.e., there is no endogeneity) (chi2(2) = 3.72, Prob > chi2 = 0.1557). Overall, this additional robustness test allowed us to alleviate endogeneity concerns and confirm that the results reported before in the probit models are appropriate.

In addition to the previous robustness check, we carried out additional empirical analyses using an alternative measure for "APD," also based on previous research. In the robustness check, this variable is measured by the ratio of the number of partner types in the SME's alliance portfolio to the maximum potential number of partner types, squaring the result (de Leeuw et al., 2014). As Table 4 displays, the main results are consistent with previous analyses.

Finally, for a better understanding of the results obtained, Figs. 1 and 2 plot the predictive margins of eco-innovation. In particular, we plot the average partial effects of the interactions between prior experience from national collaborations and APD and prior experience from international collaborations and APD to observe the impact on eco-innovation. In probit models, for a more meaningful interpretation of moderation effects, "the graph illustrates the expected values of Y for different values of X, and high and low values of Z" (Dawson, 2014, p.10). Figure 1 shows that possessing a highly diverse set of partners in the alliance portfolio reduces the positive relationship between past experience from national collaborations and the propensity to eco-innovate. To illustrate, when the APD = 0, the plot shows the positive effect of previous experiences from national collaborations on the probability to eco-innovate. However, when the APD increases to moderate/high levels (e.g., 10 and 20), the positive effect of prior experience from national collaborations on the probability to eco-innovate becomes weaker and diminishes. The same patterns are observed in Fig. 2, which shows a similar negative moderating effect of APD on the relationship between past experience in international collaborations and the propensity to eco-innovate. For example, for SMEs not engaged in diverse portfolios (APD = 0), the previous learning from international collaborations positively impacts the likelihood to eco-innovate. However, this positive effect weakens and is further reduced for SMEs that are engaged in diverse partnerships in their portfolio (e.g., APD = 20). Thus, our results show that in the case of SMEs, broader portfolio diversity negatively affects the relationship between experience from collaborations and eco-innovation, regardless of whether the latter is national or international.

## 4 Discussion and implications

In a world continuously challenged by climate change and resource scarcity, among other sustainability issues, SMEs are finding new opportunities to foster eco-innovation as a strategy that leads to competitive advantage, the resolution of society's problems, and economic growth. Given that environmental innovations are, in general terms, more complex than non-environmental ones (Barbieri, et al., 2020), they may require the co-creation by different partners. For example, Denmark has created a green industrial park, called *GreenLab*, where academia, industry, and government co-create green energy solutions (GreenLab, 2021). Similarly, the MIT Plasma Science and Fusion Center (PSFC) collaborates with the Commonwealth Fusion Systems (CFS) to develop superconducting magnets to generate green electricity (MIT, 2022). At the international level, we can also find examples of environmental co-creation like the *HyMethShip* initiative that involves 13 partners (universities, research centers, and firms) from 6 European Union countries to develop hydrogen-fuel ships (HyMethShip, 2021). As environmental innovation results from complex knowledge recombinations as well as cumulative learning processes, in this research, we examine how SMEs' prior experience and participation in collaboration networks, with different partners in different geographic locations, i.e., national and international, influence the chances of producing eco-innovative outcomes. Although the importance of geographic proximity in innovation networks is widely acknowledged, especially for innovative start-ups (Audretsch & Belitski, 2023c) and SMEs, the literature still presents ambiguous findings (Delgado-Márquez et al., 2018). Thus, our study contributes to the literature on how distinct alliance learning experiences affect innovation results (Wang et al., 2022), an aspect that has received scarce attention in the eco-innovation literature, in SMEs, and with a focus on OLT and network geography. Furthermore, we explore how APD affects these relationships, providing novel insights into innovation dynamics based on the intersection between open innovation activities and learning in

**Table 4** Robustness test. Probit random effects models. Dependent variable: eco-innovation

| Variables | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Firm size | 0.291*** | 0.289*** | 0.290*** | 0.289*** |
| | (0.026) | (0.026) | (0.026) | (0.026) |
| Internal R&D | 0.082*** | 0.082*** | 0.082*** | 0.082*** |
| | (0.004) | (0.004) | (0.004) | (0.004) |
| External R&D | 0.017*** | 0.017*** | 0.017*** | 0.017*** |
| | (0.004) | (0.004) | (0.004) | (0.004) |
| Patents | 0.104** | 0.102** | 0.102** | 0.102** |
| | (0.043) | (0.043) | (0.043) | (0.043) |
| Technological infrastructure | 0.021*** | 0.020*** | 0.020*** | 0.020*** |
| | (0.004) | (0.004) | (0.004) | (0.004) |
| Training | 0.017*** | 0.016*** | 0.016*** | 0.016*** |
| | (0.006) | (0.006) | (0.006) | (0.006) |
| Market share | 0.260*** | 0.261*** | 0.261*** | 0.261*** |
| | (0.041) | (0.041) | (0.041) | (0.041) |
| New market | 0.286*** | 0.283*** | 0.284*** | 0.283*** |
| | (0.041) | (0.041) | (0.041) | (0.041) |
| Market uncertainty | 0.224*** | 0.223*** | 0.224*** | 0.223*** |
| | (0.056) | (0.056) | (0.056) | (0.056) |
| Public support | 0.131*** | 0.126*** | 0.128*** | 0.126*** |
| | (0.039) | (0.039) | (0.039) | (0.039) |
| Prior experience, national collaborations | 0.057*** | 0.060*** | 0.056*** | 0.060*** |
| | (0.015) | (0.015) | (0.015) | (0.015) |
| Prior experience, international collaborations | 0.037 | 0.048* | 0.051* | 0.048* |
| | (0.025) | (0.025) | (0.026) | (0.026) |
| APDi | 1.124 | 4.582** | 2.912 | 4.582** |
| | (1.436) | (1.979) | (1.794) | (1.992) |
| Prior experience national collaborations*APDi | | −1.720*** | | −1.720** |
| | | (0.655) | | (0.851) |
| Prior experience international collaborations*APDi | | | −1.280* | −0.001 |
| | | | (0.748) | (0.965) |
| Industry | YES | YES | YES | YES |
| Year | YES | YES | YES | YES |
| Constant | −1.232*** | −1.216*** | −1.217*** | −1.216*** |
| | (0.132) | (0.132) | (0.132) | (0.133) |
| Observations | 20,143 | 20,143 | 20,143 | 20,143 |
| Number of ident | 4488 | 4488 | 4488 | 4488 |

Standard errors are in parentheses. ***$p<0.01$, **$p<0.05$, and *$p<0.1$. Note: coefficients are marginal effects (dy/dx)

alliances. In an eco-innovative context, this study advances previous research by examining the benefits and inherent limitations associated with the duration and continuity of collaborations, as well as partner selection in alliances.

Through recurrent collaborations over time, small firms can acquire knowledge and learn and develop close bonds that enhance trust and organizational loyalty, improving mutual understanding and reducing information asymmetries between partners (Audretsch et al., 2021; Ye & Crispeels, 2021). Although, typically, the experience gained from learning from prior collaborations is found to have a positive impact on the firm's innovative outcomes, especially those with a higher

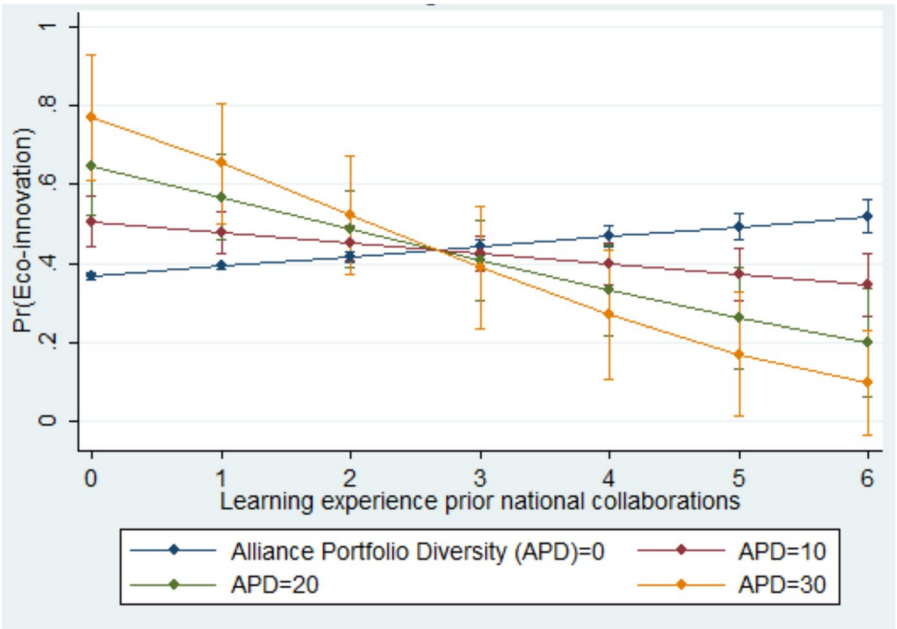


**Fig. 1** Learning from prior experience from national collaborations by alliance portfolio diversity and its relationship with eco-innovation

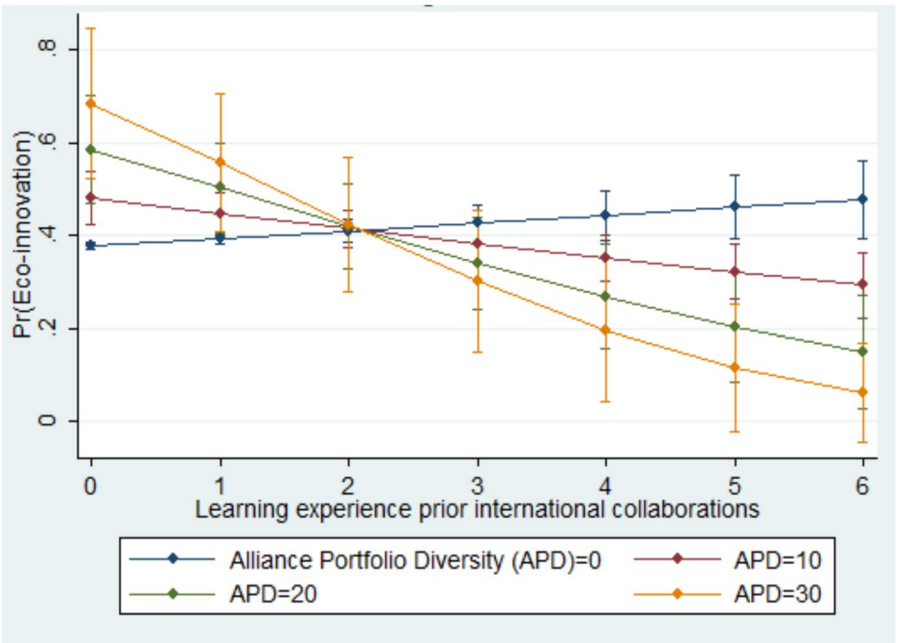


**Fig. 2** Learning from prior experience in international collaborations by alliance portfolio diversity and its relationship with eco-innovation

degree of novelty (Nieto & Santamaría, 2007), as is the case for eco-innovations, our findings show variations when we consider domestic and international contexts. In particular, in a national scenario, as predicted by hypothesis 1, our analyses confirm that prior learning from national collaborations positively affects the likelihood of introducing environmental innovations. However, hypothesis 2, in which we expect a positive effect of prior learning experience from international collaborations and eco-innovation, is not supported. These results are consistent with past research that suggests that innovators that possess limited resources, such as small firms, gain more from national collaborations compared to international collaborations, as they

avoid an increase in cooperative and other miscellaneous costs (Audretsch & Belitski, 2023a). Additionally, this finding can be explained by the difficulties that learning and absorbing knowledge and spillovers from distant partners and locations entail as a resource that is geographically bounded and not easy to replicate in other places (Audretsch & Belitski, 2023a). In an eco-innovative context, this situation is critical because SMEs generate environmental in-learning processes through their collaborations, which allow them to access partners' broad and tacit knowledge, leading to a better understanding of environmental opportunities and a higher level of engagement in eco-innovative processes (Donbesuur et al., 2021).

It is a fact that the geographical boundaries of collaborations are blurring—as countries and firms continuously improve their digital infrastructures, making global and richer knowledge sources quickly available through digital technologies (Audretsch & Belitski, 2023a; Delgado-Márquez et al., 2018). However, the process of knowledge learning, acquisition, and assimilation may become complicated, as it requires investing in improving internal capabilities, promoting trust among partners, becoming familiar with foreign market regulations, and dealing with complex negotiations and communication issues, which may make firms rule out international collaborations in favor of national collaborations, especially if small firms have limited resources and are willing to cut out costs (Audretsch & Belitski, 2023a). Overall, in line with Hsieh et al. (2018) and framed within OLT, our research shows that firms do not always learn from their previous linkages effectively, in this case, for eco-innovative purposes. SMEs frequently encounter fewer difficulties learning from domestic partners that share a similar culture, language, and institutional background to understand the complexity embedded in eco-innovations and boost the production of novel green outcomes. Furthermore, in this context, such firms can also benefit to a greater extent from the absorption of knowledge spillovers (Audretsch et al., 2021).

Our study also concludes that SMEs' APD has a negative moderating effect on the relationships between prior experience from national and international collaborations and the likelihood of eco-innovation, consistent with hypotheses 3 and 4, respectively. Previous studies have analyzed the direct relationship between APD and innovations, finding a positive, a negative, and a threshold relationship (Lee, et al., 2017). That is, low diversity levels may be beneficial for developing innovations until diversity reaches a certain threshold where it becomes detrimental. For instance, Bao et al.'s (2022) analysis of knowledge diversity over environmental innovations showed that related knowledge diversity exerted a positive influence, whereas unrelated knowledge diversity was detrimental for generating environmental innovations.

Although studying the direct link between APD and innovation goes beyond the scope of our work (see Lee, et al., 2017, for a comprehensive review), this line of reasoning could be applied to our work. In this regard, when firms embark on collaboration with a diverse set of partners, they are facing some degree of diversity. Then, combining this diverse collaboration with a cognitively distant portfolio may add too much diversity, hence resulting into a negative moderating effect. Additionally, our work is based on SMEs, i.e., firms with significant resource constraints, which may make them less resistant to diversity than large corporations. Accordingly, our analysis concludes that SMEs may be overwhelmed by sources of knowledge that are too different, as they do not provide a clear direction to tackle environmental issues and require a large amount of time and resources to become assimilated. In this regard, Marhold et al., (2017; p.7) remark on the "difficulty to identify useful knowledge," which can be exacerbated by the limited resources posed by SMEs. Our analysis shows that these firms should focus on and exploit a limited set of knowledge. In this regard, Benhayoun et al.'s (2020) analysis of SMEs engaging in collaborative innovative networks shows that the larger their cognitive distance from their partners is, the higher the effort they have to make to assimilate the constraints and advantages of the knowledge acquired. In the environmental arena, this result is in line with Leyva-de la Hiz et al. and's (2019a, b) analysis of environmental patents, which shows that focusing on few technologies yields better performance than diversifying the environmental portfolio.

In addition to our scholarly contributions, the results of our investigation present some managerial implications. As explained before, learning processes are key for SMEs in need of external knowledge inputs that can be recombined with internal knowledge inputs for eco-innovative purposes. However, prior experience can also lead to inertia and rigidity, incompatible with new

environmental technologies that emerge from radically new changes. When confronted with this situation, SME managers need to bear in mind that domestic partners may make learning processes from complex collaborations for environmental innovation smoother. Mutual understanding works better under these circumstances than it does in an international setting, as it also encourages face-to-face contact and better coordination due to similar cultural backgrounds. Notably, although it is well established in the literature that the greater the APD is, the greater the number of innovation opportunities (Capaldo, 2007; Srivastava & Gnyawali, 2011), this is a factor that negatively interacts with SMEs' learning processes for eco-innovation, as it adds high complexity (e.g., multiple functional partners and multiple locations) that these types of firms usually cannot handle due to the increased coordination costs (Kobarg et al., 2019; Wagner & Zidorn, 2017). In other words, the more experience SMEs gain from learning from local and domestic partners, the more focused and less diverse the alliance portfolio should be, considering those partners that are strategic for the firm's eco-innovative objectives. Our findings confirm the idea that SMEs with limited resources and involved in the uncertain eco-innovative process find it more difficult to capture value from the knowledge gained from international sources, given that it also needs to be adapted to local specifications and regulations, as it was originally created in distinct cognitive and technological contexts via international networks (Audretsch & Belitski, 2023a).

Finally, this study has some limitations that open new research streams. For instance, although our work provides insights into how APD may influence the organizational learning of SMEs that want to develop environmental innovations, the strategic alliance literature acknowledges that portfolio diversity is not the only factor that influences organizational learning (see the work of Kohtamäki et al., 2023, for a recent and extensive review). In this regard, future studies can explore other factors that affect organizational learning in alliances, such as the quality and depth of the knowledge shared, how frequent the exchange is between parties (Kobarg, et al., 2019), whether the organizations share central (i.e., core) or peripheral knowledge (Delgado-Márquez et al., 2018), and whether the knowledge shared can be effectively applied by the organization. Accordingly, future works may employ exploratory case studies since such studies may provide a perhaps less generalizable but more comprehensive understanding of complex phenomena such as organizational learning (Eisenhardt & Graebner, 2007; Yin, 2009). Another limitation of our work is that our empirical analyses are based on a sample of Spanish firms; thus, this research should be replicated in other countries to corroborate the validity of these results in other geographical settings with different institutional frameworks. Furthermore, regarding the variables of the study, we believe that empirical analyses that could capture the number of collaborations SMEs possess, beyond a broader variable that takes into account the breadth of partners and geographies in APD, would enrich the results provided in this study. Along these lines, it would be interesting to analyze the specific composition of the alliance portfolio in terms of partners (e.g., customers and suppliers) and geographies and how they all contribute to environmental innovation development. In addition, eco-innovation could be measured considering other well-accepted measures in the literature, such as environmental patents (Leyva-de la Hiz et al., 2019a, b) or the number of green products introduced, which unfortunately are not available in the databases based on the Community Innovation Survey.

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**Declarations**

**Competing Interest** None.

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