Networking for sustainability: Alliance capabilities and sustainability-oriented innovation

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Research on open innovation and sustainability suggests that alliances with external stakeholders help to improve innovation outcomes. This paper taps into the intersection of these literatures and investigates how alliance proactiveness and alliance portfolio coordination affect firms' sustainability-oriented innovation (SOI) outcomes. Data were collected from 170 firms in the Basque Country region in Spain, which has a highly collaborative regional innovation system. Partial least squares (PLS) modeling confirmed that alliance proactiveness is positively related to radical SOI, while alliance portfolio coordination is positively related to incremental SOI. In addition, these two capabilities involve a positive interaction effect in the case of radical SOI. An additional set of post hoc tests using latent class analysis (FIMIX-PLS) provided further evidence that firms with different internal features and levels of environmental turbulence benefit to varying extents from these capabilities and their interactions. Overall, the findings of this study show the benefits of the coupled mode of open innovation and alliance capabilities in reaching positive outcomes in SOI. On the one hand, companies focusing on incremental SOI can reap greater benefits from open innovation when collaborating within their existing portfolio; while for radical SOI, alliance proactiveness is beneficial to finding disruptive partners.

Keywords: sustainability-oriented innovation, open innovation, alliance capabilities, open sustainability, alliance proactiveness, alliance portfolio coordination

1. INTRODUCTION

There is growing interest in firm-based innovation practices and processes for economic, social, and environmental value creation (Gupta et al., 2014)—otherwise known as sustainability-oriented innovation (SOI)—that integrate social or environmental goals in parallel with economic objectives (Adams et al., 2016; Klewitz & Hansen, 2014). While such process impact on the triple bottom line of individual firms, they can also generate wider positive effects on society and the natural environment by virtue of changes in consumer behavior and the value chain as a whole (Geels, 2005). Indeed, innovation has been characterized as one of the most effective strategies for businesses seeking to contribute to sustainable development (Hall & Vredenburg, 2003). This includes both incremental and radical SOI. For instance, Procter & Gamble is sourcing more plants and renewable ingredients as raw materials and aims to change consumer behavior at home by designing detergents specifically for cold-water washing, thereby contributing to reduced CO2 emissions (Procter & Gamble, 2016). Furthermore, Unilever is collaborating with its suppliers to develop new crop yields and forms of production that will enhance biodiversity and reduce the environmental impact of farming (Unilever, 2017).

However, the inclusion of new social and environmental goals introduces further complexity and challenges into the innovation process (Hansen et al., 2009; Iñigo & Albareda, 2019). To tackle such challenges, firms often engage in alliances with other organizations, allowing mutual access and integration of required resources and capabilities (Goodman et al., 2017; Holmes & Smart, 2009; Iñigo et al., 2017). Alliances that are formed for innovation purposes have been called the *coupled mode of open innovation*, where knowledge, resources, and capabilities flow between actors in both directions, resulting in joint value creation (Enkel et al., 2009; West & Bogers, 2014). Therefore,

open innovation—particularly the coupled mode of it—can be viewed as a feasible way to improve SOI (e.g., Lopes et al., 2017).

From the focal firm perspective, reaping innovation (or other) benefits from alliances requires capabilities in managing those relationships—in other words, alliance capabilities (Sarkar et al., 2009; Schilke & Goerzen, 2010). Alliance capabilities are useful both to find new alliance partners as well as to coordinate and manage existing relationships (Bianchi et al., 2011; Degener et al., 2018). Such capabilities are known to be of relevance in managing SOI processes (Castiaux, 2012; van Kleef & Roome, 2007), and there is also evidence that incremental and radical forms of SOI require different capabilities (Carayannis et al., 2015). However, the existing literature on the intersection of sustainability and open innovation contexts provides scant evidence of the utility of such capabilities for focal-firm SOI outcomes (Behnam et al., 2018; Goodman et al., 2017). For instance, whereas the linkage between coupled open innovation and SOI has been explored in previous literature (e.g., Holmes & Smart, 2009; Lopes et al., 2017), most of such research addresses the role of intervening stakeholders and sources of knowledge (e.g., Ben Arfi et al., 2018). In fact, while alliances and collaboration are known to be of importance for SOI (Ayuso et al., 2006; Dangelico et al., 2013; de Medeiros et al., 2014; Ghisetti et al., 2015), there is little empirical evidence concerning the relationship between the alliance capabilities of the focal firm and various types of SOI outcomes. Furthermore, open innovation literature has focused mostly on other capabilities—such as absorptive capacity (e.g. Enkel & Heil, 2014)—rather than alliance capabilities in explaining how firms can reap benefits from alliances (Dittrich & Duysters, 2007; West & Bogers, 2014).

To bridge the above-mentioned research gaps, our study poses the following question: *How are different alliance capabilities related to SOI outcomes?* We focus here on two capabilities: alliance proactiveness and alliance portfolio coordination (Sarkar et al., 2009; Schilke & Goerzen, 2010). Whereas alliance proactiveness relates mainly to the pre-formation stage, when firms are searching proactively for new alliance opportunities, alliance portfolio coordination relates to the post-formation stages (Faems et al., 2010; Wang & Ragagopalan, 2015). The present study integrates discussion of sustainability-oriented and open innovation in examining how SOI can be facilitated through alliance capabilities and how these relate to incremental and radical SOI outcomes.

2. CONCEPTUAL BACKGROUND

In recent years, SOI has emerged, in line with corporate strategies for sustainable development, as a means of addressing social and environmental issues while creating economic value (Jay & Gerand, 2015; Adams et al., 2016). There is evidence that SOI has certain particularities that distinguish it from other forms of innovation, including a strong collaborative component (Iñigo & Albareda, 2016). In particular, the development of SOIs emphasizes co-creation and external knowledge search (Ben Arfi, 2018; Goodman et al., 2017), drawing on the complementary resources that alliances offer to manage the added complexity entailed by this form of innovation (Hansen et al., 2009). The following subsections explore the concepts of SOI and open innovation and alliance management capabilities, as well as related contextual considerations.

2.1 SOI and open innovation

Innovation and business sustainability, which have shared roots in organizational culture (Büschgens et al., 2013; Maurer et al., 2011) and business strategy (Aragón-Correa & Sharma, 2003; Teece, 2010), have been identified as sources of long-term competitive advantage and firm differentiation (Lengnick-Hall, 1992; Porter, 1985; Porter & van der Linde, 1995; Rodríguez et al., 2002). The relationship between innovation and business sustainability has also been highlighted in recent studies

examining the increasing importance of environmental and social sustainability as drivers of innovation (Adams et al., 2016; Doran & Ryan, 2014; Nidumolu et al., 2009; Van Kleef & Roome, 2007). These issues have recently been elaborated in the study and practice of SOI (Klewitz & Hansen, 2014; Iñigo & Albareda, 2019), which involves processes and organizational changes such as resource eco-efficiency, minimizing environmental and social impacts, eco-design of products and services, and recirculating waste into the productive economy (see, e.g., Bocken et al., 2014; Adams et al., 2016).

Given the growing interest in SOI, recent research has examined its different dimensions and levels (Adams et al., 2016), capabilities required in firm-level SOI (Iñigo et al., 2017), and the roles of various relevant stakeholders (Goodman et al., 2017). As innovation practices become more complex, there are often contradictory trade-offs among social, environmental, and economic goals (Fichter, 2005). In engaging a more diverse range of stakeholders, SOI must also address system-level challenges (Carrillo-Hermosilla et al., 2010; Iñigo & Albareda, 2016) that relate fundamentally to the need to engage with external innovation partners and social and environmental stakeholders (Goodman et al., 2017; Lopes et al., 2017) in the search for new knowledge and capabilities from external sources (Iñigo & Albareda, 2019). In doing so, firms must cross traditional boundaries to integrate specialists and to network with external knowledge and competence providers (Ben Arfi, 2018; de Marchi, 2012). For instance, Van Kleef and Roome (2007) investigated the capabilities required for sustainable business management (considered as an organizational innovation), which actively involves a broader and more diverse network of actors than more conventional forms of innovation.

For the above reasons, we find it useful to view SOI through open innovation lenses (Lopes et al., 2017), thereby allowing the systematic organization of innovation processes to become more open to external knowledge, ideas, and R&D (Chesbrough, 2006a; Chiaroni et al., 2010). Open innovation can be defined as "a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model" (Chesbrough & Bogers, 2014:1). Building on this perspective, open SOI refers to how economic, social, and environmental value creation link to open innovation practices, processes, and strategies in framing new inter- and intra-organizational relationships with innovation partners and social and environmental stakeholders. Hence, companies following open SOI practices benefit from the engagement and nurturing of alliances as a coupled mode of open innovation.

2.2 Open innovation and alliance-management capabilities

In the last decade, open innovation has become central to business strategy (Bader & Enkel, 2014), creating dedicated positions within companies and a growing field of scholarship (Almirall & Casadesus-Masanell, 2010; Barrett et al., 2011; Chesbrough, 2006a, 2006b; West et al., 2014). Literature of open innovation range from the use of inbound and outbound flows of knowledge to particular practices, capabilities, and context dependencies (Dahlander & Gann, 2010; Huizingh, 2011). Other dimensions of open innovation that researchers have explored include the increasing participation of end users (Baldwin & Von Hippel, 2011; Von Hippel, 1986), the rise of partnerships combining complementary knowledge (Almirall & Casadesus-Masanell, 2010), and the importance of innovative business models that favor openness (Chesbrough, 2010). Open innovation requires the transformation of traditional, vertically integrated innovation into more collaborative organizational forms (Chiaroni et al., 2010; Levine & Prietula, 2014). In this way, firms integrate internal and external ideas and knowledge into architectures and systems, creating new paths to market while advancing their value creation model (Barrett et al., 2011; Chesbrough, 2006a; Enkel et al., 2009).

This means that open innovation entails a process of organizational transformation whereby new resources need to be acquired and new capabilities developed (Wikhamn & Styhre, 2017).

Particularly relevant to the context of our study is the above-mentioned coupled mode of open innovation, which refers to alliances and partnerships through which joint value is created (Enkel et al., 2009; Huizingh, 2011). In this coupled mode, inbound and outbound forms of open innovation often co-exist in the joint efforts of partners to develop and commercialize innovations (Enkel et al., 2009). Innovation-alliance partners usually have complementary resources and capabilities, enabling a more effective process based on the exchange and transfer of knowledge between the partners, which improves innovation performance (Dhanaraj & Parkhe, 2006). The importance of alliances for the development of successful open innovation strategies is highlighted because the alliance context provides feasible means to transfer and integrate tacit knowledge, which is usually transferred over longer periods of times (Chen, 2004; Ritala et al., 2015).

The fact that alliances play a key role in the context of open innovation (Belderbos et al., 2004; Faems et al., 2010; Neyens et al., 2010) drives companies to develop alliance-management capabilities to derive increased benefits from such alliances (Bauer et al., 2018; García Martinez et al., 2017); consequently, these capabilities (Sarkar et al., 2009) become a major requirement for companies aiming to improve their SOI outcomes (Goodman et al., 2017). Indeed, a significant body of recent theoretical and empirical work has focused on the analysis of how organizational performance is affected by alliance capabilities (Wang & Ragagopalan, 2015). As a key dimension of value creation and appropriation and of long-term performance, alliance-management capabilities represent a potential source of competitive advantage (Heimeriks and Duysters, 2007; Ireland et al., 2002). These capabilities comprise organizational processes and routines to proactively engage in alliances and govern and coordinate the dynamics across an alliance-based portfolio (Sarkar et al., 2009); moreover, they are conceptualized as routines and functions at different levels of analysis (firm, dyad, portfolio) and at different alliance stages (Forkmann et al., 2018; Wang & Ragagopalan, 2015).

There is a lot of evidence in the open innovation literature to the effect that alliance capabilities matter. Partner selection and collaboration in the context of organizational transformation necessitates consideration of the following: first, the alignment of alliances with strategy (Bader & Enkel, 2014); second, the issue of the management of alliance portfolios in accordance with their size and diversity; and third, the contextual factors that shape the development of the focal firm's open innovation approach. The relevance of internal processes of exploration and capability development for open innovation alliances has been identified (Wikhamn & Styhre, 2017). In this regard, there is potential for a virtuous cycle wherein open innovation leads to stronger innovation endeavors while the firm's previous innovation capabilities anticipate the success of its open innovation strategy (Spithoven, 2013). In this manner, the way the firm interacts with its environment and actor network directly affects its ability to organize (open) innovation (van Lancker et al., 2016).

Furthermore, open innovation tactics, which include decisions regarding which partners to engage with, must be clearly defined by strategy (Bader & Enkel, 2014). Finding an adequate degree of openness—and hence carefully selecting innovation partners to engage with—is relevant for performance since several studies have found that too little or too much openness can be detrimental to profiting from innovation alliances, depending on the type of innovation expected from the joint innovation process (Egbetokun, 2015). Therefore, an openness strategy may be more or less beneficial depending on the explorative or exploitative nature of the project (Salge et al., 2013). In addition, engaging in too many alliances might have a detrimental effect on performance because of the increased costs of working in alliances (Faems et al., 2010); thus, the capability of identifying and engaging with relevant partners is essential.

In this research, we focus on two main stages of alliance-management capabilities (Sarkar et al., 2009). First, in the pre-formation stage, *alliance proactiveness* is based on the organizational determination to identify opportunities and engage in new alliances (Sarkar et al., 2009), in other words, the capability to identify partners with which to form alliances and initiate collaboration that suit the aims of the focal firm. Thus, developing this capability is essential to a successful pre-formation stage and the integration of open innovation into the firm's core activities; it is not simply practicing openness for its own sake. Second, during the post-formation phase of alliances for innovation, new capabilities come into play—primarily, *alliance portfolio coordination*. Alliance portfolio coordination is based on the synchronization of capabilities and activities among a portfolio of partners (Sarkar et al., 2009) and includes the capacity not only to handle such a portfolio but also to effectively manage shared responsibilities, dependencies, and processes (Wang & Ragagopalan, 2015). This shows that finding the adequate breadth of open innovation alliances is not sufficient for the success of this strategy; the ability to find complementarities, areas of overlap, and manage the depth of innovation alliances with different partners is also relevant (García Martínez et al., 2017).

The innovation direction that the firm wishes to implement is also relevant in determining an appropriate portfolio size (Egbetokun, 2015) and the relevant partners (Neyens et al., 2010) since excessive breadth has been found to be detrimental, although portfolio diversity is nonetheless associated with more successful explorative innovation activities (García Martinez et al., 2017). Since inadequate portfolio breadth may lead to inefficiencies (Salge et al., 2013), firms need to understand their pre-existing knowledge and innovation capabilities in order to engage in innovation alliances that are meaningful for the firm's open innovation strategy (Chiaroni et al., 2010). Hence, developing a proactive culture that allows for the conscientious use of open innovation strategies (Patel & Husairi, 2017) that balances internal resources with the knowledge adopted through engagement in alliances (Xiaobao et al., 2013) is useful to a firm's open innovation (and SOI) initiatives.

Finally, it might be that success in open innovation is not directly related to the capabilities of the focal firm but rather to *contingency factors*. These may be internal to the firm or alliance, such as firm size (Jang et al., 2017), project type, project leader, or work environment (Salge et al., 2013), or they may be external, such as the industry the company belongs to (Huizingh, 2011). Moreover, environmental and social pressures may become drivers of open innovation strategies in certain industries (Radnejad et al., 2017), and such environmental turbulence may greatly affect the alliance-management capabilities of the firm to establish and manage open innovation alliances successfully (Arbussa & Llach, 2018). For instance, greater breadth and depth in external knowledge search strategies has a positive association with firm performance in environments of high technological dynamism but can be harmful to performance in environments of low technological dynamism (Cruz-Gonzalez et al., 2015). Environmental turbulence, that is, the degree to which "frequent and unpredictable market and/or technological changes within an industry accentuate risk and uncertainty in the new product development strategic planning process" (Calantone et al., 2003:91), might affect decision-making regarding alliance proactiveness and portfolio coordination balance. In conditions of high environmental turbulence, firms benefit from strong and redundant alliances, while in non-turbulent times, an efficiency-seeking portfolio coordination approach that removes redundancies is more beneficial (Gilsing et al., 2016).

2.3 Alliance capabilities, open innovation, and SOI outcomes

In light of the above, it has become clear that alliance-management capabilities play an important role in SOI outcomes by providing a set of complex routines and practices for the successful establishment of alliances with external partners, with the aim of integrating social and environmental goals into the

innovation process. The introduction of new organizational capabilities to support the co-creation of sustainable value (Cainelli et al., 2012; Geffen & Rothenberg; Oltra & Saint Jean, 2009; Patala et al., 2016) serves to translate the demands of sustainability into product or service development (Dahan et al., 2010; Hansen & Spitzeck, 2011; Lacoste, 2016; Ornetzeder & Rohracher, 2006). However, entering into SOI alliances may prove challenging, as resource compatibility matching is not always perfect (van Kleef & Roome, 2007); managing the process of open innovation and co-creation requires the appropriate balance of power and trust between partners (Meqdadi et al., 2017); and high transaction costs often outweigh the potential benefits of the alliance (Colombo et al., 2006). Even where strategic needs and social opportunities are major drivers of alliance formation (Eisenhardt & Schoonhoven, 1996), success will depend on the development of certain capabilities to search for, establish, enter into, and sustain alliances.

There are some obvious synergies between open innovation and SOI; among these, previous studies have identified collaboration as one of the most important success factors for SOI (de Medeiros, 2014; Ghisetti et al., 2015). Collaboration with non-profits and other actors that often are not considered in other open innovation processes represents a notable success factor (Goodman et al., 2017); however, this implies increased diversity of interests in the relationships as well as a new balance to which the focal firm needs to adapt (Holmes & Smart, 2009). As noted above, partnerships for innovation involve an array of different actors (Enkel & Gassmann, 2008), and because SOI depends on acquiring new technical or sustainability-related knowledge in support of new goals, complementarity is a key requirement. In particular, alliances and networks involving diverse partners can provide required complementary knowledge and capabilities to incorporate social and environmental goals into the innovation process (Chen & Hung, 2014; Goodman et al., 2017). As they often bring together competing interests in the value creation process, alliances have great potential to deliver sustainability (Scandelius & Cohen, 2016). However, as Rese (2006) has noted, it is important to select the right partners to ensure that value is created and appropriately distributed across the network. As described by Goodman et al. (2017), the roles of stakeholders in SOI processes include stimulator, initiator, broker, concept refiner, legitimator, educator, context enabler, and impact extender. Therefore, capabilities in managing alliance partners become important for reaping the benefits of open innovation in sustainability contexts and, in particular, for allowing the focal firm to reach beneficial SOI outcomes.

In this research we study two main SOI outcomes. *Incremental SOI* refers to innovation practices entailing marginal changes in market structure and small variations in pre-existing innovation processes (Ettlie et al., 1984; Dewar & Dutton. 1986). For instance, incremental SOI includes innovations that improve the material or energy efficiency of existing products or help a community to access an existing technology. In general, incremental SOIs marginally improve the previous social, environmental, and economic status quo. In contrast, *radical SOI* introduces profound changes to markets and organizational structures, based on substantial changes and new innovation practices and processes (Bourreau et al., 2012; Crossan & Apaydin, 2010). Innovations that produce a change in the entire socio-technical system are considered radical SOIs. For instance, in the mobility sector, electric cars and car-sharing platforms as organizational innovations require changes throughout the entire distribution network (Steinhilber et al., 2013). Because of their more obvious potential for change, radical innovations have often received more attention in the literature, but incremental innovation is more prevalent and remains the major contributor to SOI (Jansen et al., 2009).

3. HYPOTHESIS DEVELOPMENT: ALLIANCE CAPABILITIES AND SOI

In exploring how firms may profit from entering into alliances, firm alliance capabilities are a central construct (Bauer et al., 2018; Dittrich & Duysters, 2007; Sluyts et al., 2011). In the case of SOI

alliances, success can be measured by the capacity of the alliance (or of the firm's overall alliance portfolio) to produce SOI outcomes (Sarkar et al., 2009). Alliances require different capabilities at different stages (Schilke & Goerzen, 2010), and the literature highlights two major stages in alliance management: pre-formation and post-formation (Wang & Ragagopalan, 2015). During pre-formation, firms identify and select partners compatible with the aims of the alliance, whereas post-formation involves sustaining the relationship with the selected partner to create and capture value. The present study empirically examines the alliance capabilities involved in both stages. Adopting a focal firm-centric alliance portfolio view, we focus on firm-specific capabilities in managing the search for new alliance partners (pre-formation) and coordinating the firm's current alliance portfolio (post-formation). In particular, we operationalize the pre-formation stage in terms of the construct of alliance proactiveness, while the post-formation stage is operationalized as alliance portfolio coordination (Sarkar et al., 2009). In the following sections, we develop four main hypotheses to test and measure the impact of alliance capabilities on SOI outcomes, distinguishing between incremental and radical SOI.

3.1 Alliance proactiveness and SOI

According to Schilke and Goerzen (2010) and Sarkar et al. (2009), alliance proactiveness includes a set of routines that enable a firm to improve its performance by discovering and pursuing new partners, networks, and alliances. Sarkar et al. (2009) characterized proactiveness as a multidimensional concept, referring to an organization's ability to have an effect on its environment through its own activities (Krueger, 1993), seizing new opportunities for value creation and appropriation by scanning the environment and taking preemptive action before its competitors. This higher level of alliance proactiveness can have a positive effect on market-based firm performance. In an innovation context (see also Sarkar et al., 2009), alliance proactiveness refers to organizational routines, processes, structures, and functions that determine how firms search for and initiate new alliance opportunities. By scanning their environment and approaching previously unidentified partners, firms can leverage new value creation opportunities (Sluyts et al., 2011). To incorporate social and environmental concerns in the innovation process, firms must search for new sustainability-based opportunities (Ben Arfi et al., 2018; Nidomulu et al., 2009). As the integration of cleaner technologies, eco-design, and eco-efficiency processes to reduce negative operational impacts inevitably increases the complexity of the innovation process (Adams et al., 2016), the focal firm may need to acquire new knowledge and competences (Klewitz & Hansen, 2014). Given the importance of alliance formation for the development of SOI (de Medeiros, 2014; Ghisetti et al., 2015; Lacoste, 2016), we would expect alliance proactiveness to impact positively on firm performance in terms of SOI outcomes. In fact, according to Leischnig and Geigenmüller (2018), alliance proactiveness contributes to increased market performance across different contingency configurations and degrees of market dynamism. However, the capabilities required for incremental and radical innovation will differ (Chang et al., 2012; Francis et al., 2003; Herrmann et al., 2007; Oerlemans et al., 2013) depending on the scale of SOI.

In the case of incremental SOI, alliance proactiveness facilitates innovation in several ways: 1) by identifying new partnering opportunities; 2) by evaluating the complementarity and fit of new partners; 3) by providing entrepreneurial skills to access new partnerships; and 4) by identifying new value propositions. As an example, firms may want to identify relevant partners to understand social needs to improve the social performance of their product—as did Novo Nordisk's program for early involvement of patients in the insulin improvement R&D process through partnership with the European Patients' Academy on Therapeutic Innovation (Novo Nordisk, 2018). This requires the correct identification of partners and an entrepreneurial strategy to approach and involve them in the innovation process (Iñigo & Albareda, 2019). First, firms need to monitor and scan the environment

to identify both sustainability-based opportunities and new partnering opportunities with sustainability-oriented technological, social, and environmental stakeholders (Goodman et al., 2017; Lopes et al., 2017; Patel & Huisari, 2018). Incremental opportunities are typically found in close proximity to the focal firm's knowledge portfolio (see, e.g., Ritala et al., 2017), but accessing such opportunities depends on deliberate search behavior—in other words, on alliance proactiveness (Neyens et al., 2010; Patel & Huisari, 2018). A second key component of alliance proactiveness is the development of new information-gathering techniques to identify prospective partners, supported by new methods of analysis (Sarkar et al., 2009). This facilitates the identification of new sustainability-related trends and market opportunities (Van Kleef & Roome, 2007) and assessment of potential new alliances (Bader & Enkel, 2014). Third, proactive firms acquire entrepreneurial skills that enable them to identify new partners with better knowledge of the technology, that enjoy greater demand, or that possess superior tools before their competitors can (Goodman et al., 2017). For incremental SOI, proactive firms can engage with innovation partners and social and environmental stakeholders to improve innovation practices and processes, leading to improvements in their products and services (de Medeiros et al., 2014). Finally, alliance proactiveness includes an ability to approach potential partners with new value-based propositions by facilitating engagement and sharing opportunities with innovation partners and external stakeholders. At best, social and environmental stakeholders may be convinced to participate in new forms of alliance and partnership that differ from their main activities (Nidomulu et al., 2009). On that basis, we propose the following hypothesis.

> Hypothesis 1a: *Alliance proactiveness is positively related to a focal firm's incremental SOI outcomes.*

In contrast to incremental SOI, radical SOI is highly complex, entailing profound changes in innovation practices and strategies (Herrmann et al., 2007). Such outcomes often follow major organizational change and the emergence of new sustainable business models (Bocken et al., 2014; Chiaroni et al., 2010; Wikhamn & Styhre, 2017) that require cross-sectoral collaboration and divergence from the firm's usual innovation pathway (Boons et al., 2013; Sartorius, 2006; Hansen & Spitzeck, 2011). While radical SOI requires the same kinds of routines, practices, and structures as does alliance proactiveness (as described above), sourcing external knowledge and expertise becomes especially vital because radical innovations benefit from distant knowledge beyond that of typical industry partners (e.g., García Martínez et al., 2017; Ritala et al., 2017). Firms pursuing radical SOI must therefore be able to generate not only entrepreneurial capabilities as a key dimension of core strategic transformation (Schaltegger & Wagner, 2011) but also new sustainable business models through collaboration with new types of partners (Bocken et al., 2014).

In cases of radical SOI, alliance proactiveness can improve the focal firm's output through 1) the identification of new strategic partners, particularly in relation to sustainability-related opportunities; 2) the cultivation of partnerships with partners already spearheading sustainability; and 3) the preemption of competitors in pursuit of partners with truly novel capabilities (Lin, 2012; Sarkar et al., 2009). An example of when firms exercise this capability can be found in General Electric's Ecomagination program, whereby the firm identifies startups that are pioneering environmental innovation through an open challenge to engage in product development alliances with them (GE, 2018). In the first phase, this means monitoring radical sustainability environments to identify new opportunities and potentially disruptive social and environmental partners. In many cases, these partners aim to transform the market through new sustainable business models (Bocken et al., 2014), as in the case of multi-stakeholder initiatives and/or new social and sustainable entrepreneurs (Schaltegger, Hansen, & Lüdeke-Freund, 2016), including B-corporation networks, circular economy networks, social innovation networks, and bottom-of-the-pyramid networks. Second, firms can set up

new routines and structures that alert them to market developments and trends that may lead to opportunities and alliances. For instance, sustainability-based trends analysis, including future-scenario planning, can help firms to understand how sustainability-oriented values and ideas (e.g., UN Sustainable Development Goals) may affect their business. Third, and crucially, alliance proactiveness means preempting competitors by entering into alliances (Sarkar et al., 2009), generating radical innovation-alliance proposals, and engaging with valuable innovation partners. These external partners must be willing to promote riskier forms of SOI with complementary competencies that contribute positively to such developments (Rohrbeck et al., 2013). On that basis, we propose the following hypothesis.

> Hypothesis 1b: *Alliance proactiveness is positively related to a focal firm's radical SOI outcomes.*

3.2 Alliance portfolio coordination and SOI

Alliance portfolio coordination capability includes the ability to identify synergies and avoid areas of overlap; to exploit areas of complementarity; and to identify mutual dependencies (Schilke & Goerzen, 2010). This capability relates mainly to the integration and synchronization of existing alliances to increase knowledge flows and information quality across the firm's existing portfolio (Goerzen, 2005; Sarkar et al., 2009). In contrast to alliance proactiveness, alliance portfolio coordination is about sustaining relationships with existing partners and exploiting interdependencies (García Martínez et al., 2017; Sarkar et al., 2009).

Alliance portfolio coordination includes a set of organizational processes, routines, and functions generated by the focal firm to integrate and synchronize alliance partnering activities, strategies, and knowledge that encompass many different partners in the alliance network (e.g., R&D centers, universities, end users, consumers, suppliers, research labs) (Schilke & Goerzen, 2010; Wang & Ragagopalan, 2015). The strategic benefit of portfolio coordination is to transform a set of disconnected alliances into a portfolio in which complementary assets work toward the same goal (Sarkar et al., 2009). In this way, value creation processes become collective, extending beyond the boundaries of the firm and requiring integration and synchronization of activities such as knowledge-generation, knowledge-sharing and flows, meetings, and other interactions, thereby coordinating agendas and timelines across the portfolio (Lopes et al., 2017).

Successful alliance portfolio coordination is made more difficult by the diversity of partners (Jiang et al., 2010), the nature of those partners (e.g., universities vs. end users), and functional diversity (Egbetokun, 2015; Jiang et al., 2010). Other key challenges for portfolio coordination include the purpose of the alliance (exploitation vs. exploration) (Neyens et al., 2010; Yamakawa et al., 2011) and the channels used (physical connection vs. virtual tools). According to Sarkar et al. (2009), an essential contradiction exists between increasing diversity of partners to increase innovation opportunities and the demands of coordination and synchronization (Egbetokun, 2015). Companies must find a balance by experimenting with coordination mechanisms and by continuously adapting and recombining coordination routines and activities in relation to information systems and partners' know-how (Sarkar et al., 2009; Xiaobao et al., 2013).

Incremental SOI involves marginal changes to the existing portfolio that require specific technological and sustainability-related knowledge (Adams et al., 2016; Holmes & Moir, 2007). Because the goals of incremental innovation are better defined from the outset, any underdeveloped competencies can be identified and offset through collaboration (de Marchi, 2012; Goodman et al., 2017). For that reason, looking for partners whose abilities and knowledge are better known—

typically, those already in the alliance portfolio—may ease and accelerate SOI (Iñigo & Albareda, 2019). This a strategy followed by companies like Unilever, which has a large portfolio of long-term alliances for innovation—as an example, innovation alliances with long-term suppliers, which result in incremental SOIs such as the development of less material-intensive packaging (Unilever, 2012). This may also reduce the diversity of collaborators as the characteristics required for incremental SOI may not differ much from those of the focal firm. As incremental SOI relates more to exploitation, previous collaborators may also more readily facilitate a shared model of value creation and appropriation. On that basis, we propose the following hypothesis.

> Hypothesis 2a: *Alliance portfolio coordination is positively related to a focal firm's incremental SOI outcomes.*

Because of the greater uncertainty of outcome, radical SOI entails higher risks and demands a long-term orientation (Bos-Browers, 2010). Here, increased levels of trust may be needed for embarking on the riskier process of radical SOI (Boons & Roome, 2005; Schaltegger & Wagner, 2011), and a previous working relationship can also increase the willingness to commit to a long-term process. However, while preserving the quality of individual alliances is important, co-creation with and across external partners who bring different mindsets and competences to the SOI process is particularly beneficial as radical SOI benefits from diverse viewpoints across multiple stakeholders (Iñigo et al., 2017). For instance, the Tata company, which maintains a diverse network of alliances, builds on crucial long-term alliances like the one it enjoys with MIT to develop radical innovations while involving other partners as necessary (MIT Tata Center, 2018). In summary, alliance portfolio coordination can facilitate the incorporation of multiple partners from different industries and settings, which helps to tap into radical SOI opportunities. On that basis, we propose the following hypothesis.

> Hypothesis 2b: *Alliance portfolio coordination is positively related to a focal firm's radical SOI.*

3.3 Interaction effects between alliance portfolio coordination and alliance proactiveness and different forms of SOI

In addition to the direct effects of alliance proactiveness and alliance portfolio coordination on both forms of SOI, we would expect to find a mutual positive interaction effect between these capabilities; in other words, we expect to witness synergies between the two capabilities regarding their role in improving firms' opportunities to reach incremental and radical SOI outcomes.

First, firms that are proactive in searching for new alliance partners can benefit from a better understanding of the types of alliances currently missing from their portfolio. Recognizing capability gaps among alliances improves the proactive search for new alliances by highlighting areas of higher value, leading eventually to improved incremental and radical SOI outcomes (Goodman et al., 2017). Furthermore, alliance portfolio coordination not only helps to improve proactive searching for new innovation, social, and environmental partners but also involves prospective alliance partners in the coordination process (Van Kleef & Roome, 2007). In particular, it helps in identifying complementarities across the current portfolio while initiating negotiations with new partners (García Martínez et al., 2017; Patel & Huisari, 2018; Schilke & Goerzen, 2010). In this way, the firm can constantly align its pursuit of potential new alliances with existing collaborations, possibly even facilitating collaboration between new and existing alliance partners through the development of trust and alliance portfolio capital (Sarkar et al., 2009).

Second, firms that pursue the coordination of their alliance portfolios also benefit simultaneously from such a highly proactive approach. Indeed, the ability to identify relevant partners for innovation alliances and approaching them in an entrepreneurial way (Sarkar et al., 2009) should be helpful in scanning and identify capability gaps in the existing portfolio, for instance, via recognizing new potential alliance partners that are missing from the portfolio or by connecting previously unrelated partners via proactive engagement across current and new alliances. Indeed, the highly systemic nature of many sustainability-related problems (Iñigo & Albareda, 2016; Whiteman et al., 2013) will benefit from integration and recombination of specialized knowledge from multiple domains (Savino et al., 2017). Thus, cross-pollination among existing and new alliance partners may prove highly beneficial for SOI outcomes.

Based on these two lines of reasoning, we would expect strong synergies between alliance proactiveness and alliance portfolio coordination for both incremental and radical SOI. On that basis, we advance the following interaction hypotheses:

> Hypothesis 3a: *There is a positive interaction between alliance proactiveness and alliance portfolio coordination in terms of their effect on incremental SOI.*
>
> Hypothesis 3b: *There is a positive interaction between alliance proactiveness and alliance portfolio coordination in terms of their effect on radical SOI.*

4. METHODOLOGY

4.1 Sample and data collection

The sample comprised firms from the Basque Country region in Northern Spain with more than 50 employees. The criterion of more than 50 employees served to increase the likelihood of SOI involvement. Additionally, our target population of innovation and/or sustainability managers were more likely to be found in firms with 50+ employees. Where no such respondent was available, CEOs or project managers were targeted instead, and our final sample included R&D managers, innovation managers, quality managers, sustainability managers, and environmental managers, as well as CEOs.

The sample was confined geographically to firms in the Basque Country region, which has a highly collaborative regional innovation system (OECD, 2011). The region is renowned for its innovation system, which is based on a high degree of inter-organizational and inter-firm collaboration (Morgan, 2016; Porto-Gomez et al., 2015). The system centers on collaboration, creation of public-private technological centers, and smart specialization, and the region is often benchmarked for its sustainability-oriented policies, in which businesses are major actors (Karlsen & Larrea, 2011). This model of a networked innovation system and sustainability positioning is of interest in studying open SOI, and the results are representative for other regions with strong innovation ecosystems. In terms of innovation performance, the region ranks well above the national average and is considered highly innovative by European standards, as well as scoring high on the Human Development Index (OECD, 2011). The database was supplied by Kompass; the 1178 firms included all Basque Country companies with more than 50 employees. Only firms with independent strategic decision-making capacity were included—in other words, branches, firms acquired by other companies, and firms owned or partly owned by the public administration were excluded from the sample. Based on this criterion and after the removal of duplicates, the total sample included 873 firms of more than 50 employees headquartered in the Basque region with sufficient capacity for strategic decision-making. We contacted all 873 of the companies, obtaining a 19.5% response rate. Using random sampling without replacement (Särndal et al., 2003), we were able to collect data from 170 of these firms, each

of which was representative of the population and had an equal chance of being selected. This is sufficiently representative to generalize the results to the whole population (Keeter et al., 2006), as confirmed by the descriptive statistics in Table 1.

Table 1 Frequencies of key variables for sample representativeness

Key variables	*Frequencies*			
Sector	Manufacturing	Trade and logistics	Services	
	55.9%	26.5%	17.6%	
Number of employees	Medium-sized (50–249)	Large (≥250)		
	71.8%	28.2%		
Firm age (in years)	5–34 years	35–69 years	70–99	≥100
	68.8%	26.50%	2.90%	1.80%
Turnover (in million €)	≤4.999	5–19.999	20–99.999	≥100
	12.4%	39.4%	34.1%	14.1%
R&D intensity (% of turnover invested in R&D)	Low (0–0.9%)	Medium-low (1–1.9%)	Medium-high (2–4.9%)	High (≥ 5%)
	23.5%	28.2%	27.1%	21.2%
Sustainability orientation	Low (1–2)	Medium (3–5)	High (6–7)	
	10.0%	45.3%	44.7%	

The most represented sector is manufacturing and the smallest group in the sample is services companies (which is nevertheless sufficiently large to be representative). The majority of firms are medium-sized enterprises; small companies were excluded from the sample. Representation by sector and size reflects the economic structure of the region (OECD, 2011). In relation to R&D intensity, the sample is fairly balanced, and medium and high degrees of sustainability orientation predominate. Although responses may reflect social desirability, it should be noted that the region spearheads sustainable development strategies in which business actors are the main players, which may account for an elevated sustainability orientation (Happaerts et al., 2010; Karlsen & Larrea, 2012).

Data were collected by phone and email between November 2015 and April 2016 (Groves, 1990; Wright, 2005). Where necessary, the participating firms were contacted first by phone to identify the most suitable respondent. Once contact was established with the target respondent, the questionnaire was either answered over the phone or sent by email for response via a web-based platform. Email reminders were sent to those who did not reply to the questionnaire on the first occasion. Combining both methods, we were able to obtain a 19.5% response rate during the agreed data collection period. Of the remaining 80.5%, 90 (10.3%) refused to answer the questionnaire; in 19 cases (2.2%), contact was never established with the appropriate person; and in 594 cases (68%), communication was terminated after three unanswered email reminders.

An ANOVA test based on five key variables identified no significant non-response bias, as illustrated in Table 2: the Student-Newman-Keuls and Tukey's harmonic means B tests were conducted post hoc (Armstrong & Overton, 1977; Lindner et al., 2001), showing that the key variables were homogenous across the four groups (telephone response, web-based response after first email, web-based response after second email reminder, and web-based response after third email reminder). Since previous research has shown that social desirability bias often appears differently in telephone and email-based surveys (Chang & Crosnick, 2009; Taylor et al., 2009), the homogeneity of the results of these different tests suggests that social desirability issues should not pose a major concern,

as the telephone respondent group did not deviate significantly from the others. The main limitation of the cross-sectional design of the study is its weaker internal validity compared to longitudinal studies because of the difficulty of establishing unambiguous causal relationships from the data as these were collected at the same point in time (although there are ways to identify such relationships during the data analysis phase) (Bryman, 2008). However, the use of a random sampling strategy meant that replicability and external validity were strong, and it is reasonable to infer sufficiently generalizable conclusions from the results of the analysis.

Table 2 ANOVA tests for non-response bias

		Sum of Squares	df	Mean Square	F	Sig.
Sustainability orientation	Between Groups	8.618	3	2.873	.972	.407
	Within Groups	490.376	166	2.954		
	Total	498.994	169			
Alliance portfolio coordination	Between Groups	2.244	3	.748	.266	.850
	Within Groups	466.512	166	2.810		
	Total	468.756	169			
Alliance proactiveness	Between Groups	4.361	3	1.454	.711	.547
	Within Groups	339.500	166	2.045		
	Total	343.861	169			
Incremental SOI	Between Groups	42.309	3	14.103	.796	.498
	Within Groups	2941.244	166	17.718		
	Total	2983.553	169			
Radical SOI	Between Groups	35.286	3	11.762	2.057	.108
	Within Groups	949.420	166	5.719		
	Total	984.706	169			

4.2 Measures

As a dependent variable, we measured *sustainability-oriented innovation* (SOI). This was operationalized as an index variable comprising 15 items and five themes (process, organization, product, service, and marketing). The themes were derived from the Oslo Manual (OECD and Eurostat, 2005). The practices described in the manual included process, organization, product, service, and marketing innovation; we added social and environmental improvement to the economic goals of innovation. The Oslo Manual is the basis for the Community Innovation Survey indicators for innovation performance, which are widely used for research (Ghisetti et al., 2015; Laursen & Salter, 2006). For each item, respondents chose from three options: 0 (= *no innovation*), 1 (= *incremental innovation*) or 2 (= *radical innovation*), as introduced in the previous year. Based on the responses to the 15 items, we built two index variables for incremental and radical SOI. There were two reasons for operationalizing incremental and radical SOI by means of index variables. First, as there is no established measure of SOI, we needed to develop a measure that would take account of the different types of SOI. To capture the complex and varying nature of innovations that improve social and environmental performance, we needed an overarching measure of these issues, and the 15 items developed across five themes served this purpose. Secondly, it was not our intention to draw inferences about other types of SOI beyond the incremental and radical. This type of index variable facilitates understanding of the breadth of SOI activities for a particular company without being overly sensitive to type of SOI. Table 3 lists all of the items across the five themes.

Table 3 Items for incremental and radical SOI indices[a]

SOI Theme	Index item (items adopted from Oslo Manual [OECD and Eurostat, 2005] and further modified to fit the study's context)
SOI (processes)	Methods of manufacturing or producing goods or services that improve the environmental or social impact of the company
	Logistics, delivery or distribution methods for inputs, goods or services that improve the environmental or social impact of the company
	Supporting activities for processes that improve the environmental or social impact of the company, such as maintenance systems or operations for purchasing, accounting, or computing
SOI (organizational)	Business practices for organizing procedures in a sustainable way (i.e., sustainable supply chain management, business reengineering, lean production, environmental management systems, etc.)
	Methods of organizing work responsibilities and decision-making to improve the environmental and social impact (i.e., sustainability education/training systems, creation of sustainability task forces, etc.)
	Methods of organizing external relations with other firms or public institutions to foster sustainability (i.e., first use of alliances, partnerships, outsourcing or subcontracting, etc.)
SOI (products)	Technologies that improve social or environmental performance
	Consumer products that improve social or environmental performance
	Products sold to other businesses that improve social or environmental performance
SOI (services)	Maintenance or after-sale services that improve social or environmental performance
	Professional services (consultancy, advisory…) that improve social or environmental performance
	Basic services, that improve social or environmental performance (i.e., waste clean-up, efficient electricity distribution, etc.)
SOI (marketing)	Maintenance or after-sale services that improve social or environmental performance
	Professional services (consultancy, advisory…) that improve social or environmental performance
	Basic services that improve social or environmental performance (i.e., waste clean-up, efficient electricity distribution, etc.)

a = During the last year, did your company introduce (tick as appropriate): No; Yes, significantly improved ones (counts as one for Incremental SOI index); Yes, completely new ones (counts as one for Radical SOI index)

The measures for independent variables were extracted from existing scales—from Sarkar et al. (2009) in the case of alliance proactiveness and from Schilke and Goerzen (2010) in the case of alliance portfolio coordination. Alliance proactiveness included partner exploration and partner selection, preempting the competition, taking the initiative, and monitoring partnership opportunities (see Table 4). Alliance portfolio coordination included analysis of alliance coordination, alliances portfolio, coordination, strategies coordination, knowledge transfer across alliance partners, and interorganizational coordination (see Table 4). Both variables have been measured by Sarkar et al. (2009) and by Schilke and Goerzen (2010). We chose Sarkar et al.'s (2009) measure of alliance proactiveness because, for equal composite reliabilities, its five items increase the chances of good internal validity. For alliance portfolio coordination, we chose Schilke and Goerzen's (2010) measure for its better composite reliability.

We employed a wide range of control variables in testing the hypotheses. First, we controlled for the classic sources of firm heterogeneity with variables for firm age, firm size (measured in sales), and industry. Second, to account for the variance in R&D efforts across firms, R&D intensity (measured

as a percentage of turnover invested in R&D) was also controlled for. Third, because of the sustainability dimension of the outcomes, we also included a measure of firms' sustainability orientation. For this purpose, we chose a simple self-assessment measure: "To what extent is sustainability a core issue for your business?" Informants were asked to respond on a seven-point scale (from 1 = *Our business is not concerned with sustainability* to 7 = *Sustainability is at the core of our business*). Finally, we controlled for the turbulence in the firms' business environment. To this end, we used the measure developed by Joshi and Sharma (2004) that applies three different multi-item measures: customer turbulence, competitor turbulence, and technological turbulence (see Table 4 for a full description of the items).

5. RESULTS

To test the hypotheses, the overall research model was analyzed using partial least squares (PLS) structural equation modeling (SEM) employing SmartPLS version 3.0. We selected PLS because it has several benefits (see, e.g., Hair et al., 2012, 2013, 2014) compared, for example, to covariance-based structural equation models. First, several key variables in our data (such as the radical SOI measure) were not normally distributed. Second, the sample size (n = 170) was small in relation to the complexity of the research model, and PLS enables effective estimation of path models in such contexts. Finally, our research design can be considered exploratory in that it examines perceived performance in incremental and radical SOI performance, and as a prediction-oriented method of estimation, PLS was considered applicable in this context.

Like other SEM techniques, PLS facilitates examination of measurement models and their structural components and provides factor loadings that can be interpreted in much the same way as principal component analysis (see, e.g., Sosik et al., 2009). Table 4 details the multi-item measures used here, along with the factor loadings, average variance extracted (AVE), and construct reliability (CR). The loadings of all the measurement items were high and statistically significant, which supports their relationship to the specific constructs. Both constructs exhibited a CR value above the threshold of 0.7 (Bagozzi & Yi, 1991). Both AVE values exceeded the cut-off of 0.50 by a large margin (see, e.g., Fornell & Larcker, 1981). Overall, these results indicate good reliability and validity for the alliance capability measures used in the empirical study.

Table 4 Constructs and measurement items for alliance capability variables

Construct	Item	Factor loading	AVE	CR
Alliance proactiveness	We actively monitor our environment to identify partnering opportunities.	0.875***	0.781	0.947
	We routinely gather information about prospective partners from various forums (e.g., trade shows, industry conventions, databases, publications, internet, etc.).	0.847***		
	We are alert to market developments that create potential alliance opportunities.	0.908***		
	We strive to preempt our competition by entering into alliances with key firms before they can.	0.894***		
	We often take the initiative in approaching firms with alliance proposals.	0.893***		
Alliance portfolio coordination	We ensure an appropriate coordination among the activities of our different innovation alliances.	0.920***	0.908	0.975
	We determine areas of complementarity in our innovation-alliance portfolio.	0.955***		
	We ensure that mutual dependencies between our innovation alliances are identified.	0.971***		
	We determine if there are areas of overlap between our different innovation alliances.	0.964***		
Customer turbulence	Customers' preferences for product or service features have changed quite a bit over time.	0.857***	0.667	0.857
	We are witnessing demand for our products from customers that never bought them before.	0.831***		
	New customers tend to have product-related needs that are different from those of our existing customers.	0.758***		
Competitor turbulence	Our competitors are constantly changing their product features.	0.879***	0.743	0.897
	Our competitors are constantly changing their sales strategies.	0.903***		
	New competitors are entering our industry.	0.802***		
Tech turbulence	The technology in our industry is changing rapidly.	0.909***	0.778	0.913
	It is unlikely that today's technological standard will still be dominant five years from now.	0.817***		
	Technological breakthroughs contribute to the development of new product ideas in our industry.	0.916***		

* $p < 0.05$; ** $p < 0.01$ (two-tailed)

Table 5 presents the descriptive statistics and correlations between the variables and allows us to assess the discriminant validity of the alliance capability-related multi-item constructs. In assessing discriminant validity, the square roots of AVEs should be greater than the variance shared between that construct and other constructs in the model (i.e., the correlation between two constructs) (Fornell & Larcker, 1981). Here, all the multi-item constructs fulfill this condition as the diagonal elements (square roots of AVEs) are greater than the off-diagonal elements for alliance proactiveness, alliance portfolio coordination as well as for the three types of environmental turbulence.

Table 5 Descriptive statistics, correlations, and discriminant validity of the measures

Variable	*Mean*	*S.D.*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
1. Incremental SOI	5.74	4.20	[a]										
2. Radical SOI	1.19	2.43	-0.07	[a]									
3. Alliance proactiveness	4.14	1.43	0.36**	0.33**	***0.88***								
4. Alliance portfolio coordination	3.59	1.61	0.39**	0.30**	0.77**	***0.95***							
5. Customer turbulence	4.24	1.20	0.25**	0.30**	0.38**	0.27**	***0.82***						
6. Competitor turbulence	3.84	1.26	0.23**	0.29**	0.47**	0.34**	0.55**	***0.86***					
7. Technological turbulence	4.49	1.29	0.26**	0.38**	0.42**	0.43**	0.48**	0.53**	***0.88***				
8. Sustainability orientation	5.04	1.68	0.37**	0.33**	0.40**	0.42**	0.36**	0.35**	0.42**	[a]			
9. Firm age	32.55	20.05	-0.69	0.18*	0.13	0.20**	0.05	0.02	-0.03	0.01	[a]		
10. Firm sales (million euros)	160.82	874.87	0.10	0.03	0.06	0.16*	0.10	0.10	0.17*	0.06	0.12	[a]	
11. R&D intensity	2.47	1.07	0.17*	0.23**	0.41**	0.43**	0.22**	0.15*	0.27**	0.34**	0.09	0.01	[a]

* $p < 0.05$; ** $p < 0.01$
S.D. = Standard deviation
a = single-item indicator

Figure 1 and Table 6 summarize the results of the PLS model. In running the models, we dropped out three responses due to missing information on several items in the alliance capability scales (resulting in a final effective n = 167). Based on the path model, alliance proactiveness is positively related to radical SOI (supporting H1b, although only at a significance level of $p < 0.10$), and alliance portfolio coordination is positively related to incremental SOI (supporting H2a). H1a and H2b were not supported. Within the full model, then, alliance proactiveness and portfolio coordination can be said to have specific benefits for different focal firm innovation outcomes. Additionally, we found evidence of a positive interaction effect (see the dotted line in Figure 1) between alliance portfolio coordination and alliance proactiveness for radical SOI, supporting H3b. However, we did not find a significant interaction effect in the case of incremental SOI. It is also noteworthy that the control variable sustainability orientation is a strong predictor of both types of SOI; this further substantiates the hypothesis testing as the strong effect of focal-firm orientation was controlled for while the hypothesized main effects and moderator effects retained their significance. Finally, of the environmental contingency variables, only technological turbulence demonstrates a significant and positive effect on radical SOI.

INSERT FIGURE 1 ABOUT HERE

Table 6 Partial least squares model results: Path coefficients and *t*-values

	Incremental SOI		*Radical SOI*	
Control variables				
Firm age	-0.135*	1.880	0.182*	1.727
Firm sales	0.051	0.606	-0.090	0.614
R&D intensity	-0.090	1.037	0.119†	1.302
Trade dummy	-0.040	0.492	0.195**	2.617
Services dummy	0.043	0.559	0.041	0.527
Sustainability orientation	0.205**	2.420	0.175**	2.590
Customer turbulence	0.111	1.230	0.063	0.109
Competitor turbulence	-0.012	0.122	0.016	0.149
Technological turbulence	0.016	0.135	0.161**	2.391
Focus variables				
Alliance proactiveness	0.010	0.084	0.244†	1.488
Alliance portfolio coordination	0.316**	3.152	-0.108	0.849
Alliance proactiveness X alliance portfolio coordination	-0.072	0.903	0.122*	1.695
$\mathbf{R^2}$	0.246**		0.286**	
$\mathbf{Q^2}$	0.119		0.136	

† $p < 0.10$; * $p < 0.05$; ** $p < 0.01$ (one-tailed)

We also conducted a series of post hoc tests. First, we examined whether there would be further (non-hypothesized) interaction effects between the control variables and alliance capabilities. We found neither strong nor significant effects in this regard. However, we still expect the sample firms to exhibit major heterogeneity regarding the studied model. Therefore, we conducted a latent class analysis using finite mixture modeling (FIMIX-PLS) in PLS, which allowed the investigation of whether the sample included meaningfully different segments regarding strength, direction or

statistical significance of the estimated model (Hair et al., 2012). Recently, this technique has been used, e.g., by Mitrega et al. (2017), who found that their sample included two very different segments for the paths between networking capabilities and product innovation. Given the sufficient similarity of our research setting, it could also be expected that there might be major differences within the sample in terms of how alliance capabilities affect incremental and radical SOI.

To conduct the latent class analysis, we first examined solutions for different numbers of potential segments (i.e., latent classes) in the sample. Ultimately, we compared the two-segment and three-segment solutions as these were the ones for which the sample size in the smallest segments was still feasible to run the path models. Based on Akaike's information criterion (AIC), the Bayesian information criterion (BIC), and the Normed entropy (EN) statistic (see, e.g., Hair et al., 2012; Mitrega et al., 2017), we selected the three-segment solution for further analysis as it demonstrated better overall fit with the previously mentioned criteria.[1]

Table 7 provides comparative descriptive statistics of the firms in the three segments, of which the significance of mean differences were tested with ANOVA, as well as with pair-wise post hoc analyses. In interpreting the significance of the post-hoc analyses, either Bonferroni or Tamhane's T2 test was used, depending on the results of homogeneity of variance test. This comparison reveals very interesting differences between the segments. The first segment (n = 95) includes firms that are fully focused on incremental SOI, are less sustainability-oriented than firms in other segments, and for which the environmental turbulence experienced is low overall. They are also smaller (in terms of yearly sales) than firms in other segments (although the mean difference here was not significant). The second segment (n = 44) includes firms that focus a lot on radical SOI and whose environmental turbulence is moderate (although the difference in environmental turbulence is mostly significant between segments 1 and 3, as shown in the post-hoc analyses). Finally, the third segment (n = 28) includes firms that could be characterized as "sustainability-oriented super-innovators": they rank high in both incremental and radical SOI, they exhibit a high level of R&D intensity and sustainability orientation, and they experience high levels of environmental turbulence.

Table 7 Characteristics of firms in three segments of the sample

	Segment 1 (n = 95)	*Segment 2 (n = 44)*	*Segment 3 (n = 28)*	*Post hoc*[a]
Incremental SOI*	5.20	5.82	7.43	1 < 3
Radical SOI*	0.15	2.05	3.39	1 < 2 < 3
Firm age	29.41	37.80	34.96	
Firm sales (million euros)	36.00	334.74	311.01	
R&D intensity*	2.33	2.50	2.89	1 < 3
Customer turbulence*	4.06	4.25	4.82	1 < 3
Competitor turbulence*	3.58	4.04	4.44	1 < 3
Technological turbulence*	4.11	4.89	5.13	1 < 2; 1 < 3
Sustainability orientation*	4.60	5.30	6.11	1 < 2 < 3

* $p < 0.05$ (Significance of mean difference; ANOVA)

[a] Post-hoc analysis based on pair-wise comparisons between segments 1, 2 and 3, ($p < 0.05$)

[1] In particular, comparing the two- and three-segment solutions yielded the following respective statistics: 601.41 vs. 558.25 (AIC), 766.66 vs. 807.69 (BIC), and 0.84 vs. 0.91 (EN). Based on these, the three-segment solution was superior regarding the AIC and EN statistics but worse for the BIC (ideally, the AIC and BIC statistics should be minimized, while EN should be maximized).

Table 8 below reports the differences in the path models of the overall model as well as between firms in three segments. Following the example of Mitrega et al. (2017), we tested the path models for different segments using only the main variables, as in the hypothesized model (this also allows for the analysis of the smaller segments in the data). It is noteworthy that in Segment 1, we could only report the results for paths pertaining to incremental SOI; there were only two responses that reported any radical SOI, and the PLS models did not load with these included. After these two were dropped, path models for Segment 1 were loaded, allowing for a meaningful comparison across models.

Table 8 Comparison of PLS results for overall model and three segments: Path coefficients and *t*-values

	Overall	***Segment 1***	***Segment 2***	***Segment 3***
Alliance portfolio coordination -> Incremental SOI	0.312 (3.697)**	0.291 (2.467)**	0.426 (2.089)*	0.244 (1.098)
Alliance portfolio coordination -> Radical SOI	0.049 (0.405)		0.025 (0.127)	-0.049 (0.181)
Alliance proactiveness -> Incremental SOI	0.112 (1.127)	0.159 (1.258)	0.062 (0.268)	-0.196 (0.571)
Alliance proactiveness -> Radical SOI	0.310 (2.275)*		0.614 (3.211)**	-0.112 (0.318)
Moderating Effect 1 -> Incremental SOI	-0.070 (0.934)	-0.086 (0.945)	-0.272 (2.144)*	0.351 (1.591)†
Moderating Effect 2 -> Radical SOI	0.127 (1.667)*		0.450 (3.695)**	-0.368 (1.654)*
R^2 (incremental SOI)	0.167**	0.187**	0.337**	0.285*
R^2 (radical SOI)	0.137*		0.516**	0.162†
Q^2 (incremental SOI)	0.130	0.137	0.223	0.023
Q^2 (radical SOI)	0.069		0.336	-0.104

† $p < 0.10$; * $p < 0.05$; ** $p < 0.01$ (one-tailed)

The overall model using just the hypothesized variables is very much aligned with the findings reported in the full model with control variables (Table 6). However, when looking at the results for Segments 1, 2, and 3, we can notice major differences in the significant paths as well as the direction of the interaction effects. First, regarding the main effects, the three segments are quite well in line with those of the overall hypothesized model. Segments 1 and 2 provide similar findings in this regard, while Segment 3 does not include significant main effects. Second, examination of the interaction effects exposes some interesting differences across the segments. Aligned with the main model, Segment 2 provides further support for the positive interaction between both alliance capabilities in explaining radical SOI. However, the interaction effect for incremental SOI becomes negative in this segment. For Segment 3, the signs of the interaction effects are reversed; there is a positive interaction effect between the alliance capabilities in explaining incremental SOI, but the interaction effect becomes negative for radical SOI. It is noteworthy, however, that the Q^2 values (measuring predictive relevance) are low or negative for segment 3 models. This is likely due to the small segment size (n = 28) as well as rather low and non-significant direct effects. Therefore, these results (especially for segment 3) should be treated with caution, and used mostly as indicative of the qualitative differences of different segments, rather than as explanatory structures.

6. DISCUSSION AND IMPLICATIONS

Our study has aimed to establish a connection between the coupled mode of open innovation (i.e., innovation alliances) and firms' SOI outcomes. In doing so, we examined how different alliance capabilities relate to incremental and radical forms of SOI. We first briefly present a discussion of

the results, followed by the theoretical and managerial implications of the study, its limitations, and suggestions for further research.

First, these results suggest that a profound transformation in sustainability practices (as in radical SOI) benefits from higher levels of *alliance proactiveness*. This highlights the benefits of an entrepreneurially oriented search for disruptive partners, possibly from other domains (e.g., environmental and social), to complement a firm's knowledge and activities (Dittrich & Duysters, 2007; Eisenhardt & Schoonhoven, 1996; Gesing et al., 2015). On the one hand, proactively looking beyond the usual collaborators is necessary in order to introduce new sustainability-oriented ideas and technologies for radical SOI that extend opportunities to new mindsets and domains (Boons et al., 2013; Lopes et al., 2017) while preempting competitors from entering these alliances. On the other hand, our results show that alliance portfolio coordination is not related to radical SOI. This potentially implies that radical inputs come from diverse and dislocated specialist sources without specific requirements for cross-alliance integration (see, e.g., Egbetokun, 2015).

Furthermore, *alliance portfolio coordination* capability seems mostly relevant for incremental SOI. Alliances contributing to incremental SOI are likely to be more important in maintaining and exploiting the outcomes of jointly developed SOIs, which highlights the role of coordination and cross-alliance integration (García Martínez et al., 2017). Indeed, the better-defined objectives of incremental innovation (e.g., operational optimization activities) (Adams et al., 2016) support the identification of necessary resources and knowledge among existing partners, thereby increasing trust and facilitating the establishment of SOI exploitation.

Aligned with our expectations, we found evidence of the positive *interaction effect of alliance proactiveness and alliance portfolio coordination* in terms of radical SOI, while there was no such effect regarding incremental SOI. For radical SOI, the result can be interpreted via the variety of resources and insights required for radical sustainability-related innovation (e.g. Adams et al., 2016; Inigo et al., 2017). Here the ability to reach radical SOI outcomes is enabled through mutual interaction between the two capabilities. On one hand, proactive firms benefit from being able to coordinate their existing portfolio's so that the knowledge accessed from new partners can be coupled with the existing partnerships, leading to new and radical recombinations of knowledge (Rosenkopf & Almeida, 2003; Savino et al., 2017). On the other hand, firms' coordination of their alliance portfolios will benefit from proactiely searching for new partnerships to fulfill the knowledge and resource gaps needed to realize radical innovation. In terms of incremental SOI, we did not find support for a positive interaction between the two alliance capabilities in our main model. This could be interpreted based on the difference between two types of innovation. Reaching succesful outcomes for incremental SOI does perhaps not require strong interplay of these capabilities, given the lower requirements for diverse knowledge combination needed for this type of innovation (e.g. Inigo et al., 2017).

Finally, through a series of post hoc tests, we identified three main segments with varying degrees of SOI, R&D intensity, sustainability orientation, and environmental turbulence experienced. The first segment involved "incremental innovators" – i.e firms that operate under conditions of low environmental turbulence and focus almost exclusively on incremental SOI (Segment 1). Based on our results, these types of firms benefit mostly from alliance portfolio coordination, while proactiveness is not as important. This is intuitive from the perspective that incremental innovation benefits from local search (via utilizing existing knowledge sources), rather than distant search (e.g. via accessing new partners, see Rosenkopf & Almeida, 2003). The second segment involved the "middle-ground firms" – those that focus on both incremental and radical SOI and that face moderate environmental turbulence. For these firms, alliance portfolio coordination is similarly relevant for

incremental SOI for the same reasons as it is for the previously mentioned incremental innovators. However, firms in this segment also benefit from alliance proactiveness in radical SOI outcomes. Here, the proactive approach to open innovation is required to access radically new ideas via external alliances, as suggested by previous literature (Bader & Enkel, 2014; Ben Arfi et al., 2018; García Martinez et al., 2017). Furthermore, for Segment 2 firms, the two capabilities exhibit synergies (positive interaction) in terms of radical SOI and a substitutive role (negative interaction) for incremental SOI. Here, for these firms it seems that investing a lot on new alliances as well as coordinating existing portfolio effectively pays off in enablign radical recombinations of knowledge, as required for radical SOI. However, similar intensive approach turns out to be harmful for incremental innovation, potentially due to "over-searching", i.e. investing exessive efforts to new knowledge search while distracting attention and focus (Laursen & Salter, 2006). Lastly, we labeled Segment 3 firms as "sustainability-oriented super innovators" due to their high levels of sustainability orientation, R&D intensity, outcomes in incremental and radical SOI, as well as the environmental turbulence experienced. For these firms, we did not find significant direct role for either alliance capabilities. This might be due, on the one hand, to their major internal R&D efforts and resources, which lead them to benefit relatively less from open innovation. On the other hand, these firms experience positive synergies from using the two capabilities in incremental SOI, while for radical SOI, the effect becomes substitutive. As these interaction effects differ from what we witness for other firms, as well as in the full sample models, it suggests that this group operates under a different logic in their innovation activities. However, due to small sample size in this segment, these results should be interpreted with caution, and further research is needed to reveal how these types of companies can best utilize external networks and ecosystems in their SOI efforts. Nevertheless, the latent class analysis demonstrates that the contingencies and context matter for open innovation and SOI alike, and it is beneficial to view the applicability of alliance capabilities in the light of a firm's internal features as well as its business environment.

6.1 Theoretical implications

In contributing to an understanding of the internal dynamics of open innovation and sustainability in business markets, our study provides implications for three streams of literature: 1) open innovation, 2) SOI, and 3) alliance capabilities and alliance management.

First, we demonstrate the crucial role of the *coupled mode* of open innovation (Enkel et al., 2009) – i.e alliances (Belderbos et al., 2004; Faems et al., 2010; Neyens et al., 2010) – in sustainability contexts. In fact, the literature combining open innovation and business sustainability is still a rather underexplored territory, and therefore our study answers to the calls for better understanding of the contexts of open innovation (Arbussa & Llach, 2018; Cruz-Gonzalez et al., 2015; Huizingh, 2011; Radnejad et al., 2017). Our study provides quantitative evidence of how firms can manage their alliance portfolios in reaching both incremental and radical SOI outcomes. These insights complement the existing analyses on knowledge sources contributing to sustainability (i.e., in-bound open innovation; see, e.g., Ben Arfi et al., 2018) as well as qualitative analyses demonstrating the benefits of focal firms forming alliances and networks for sustainability purposes (see, e.g., Holmes & Smart, 2009; Lopes et al., 2017). This, in turn, advances previous research on SOI and stakeholder collaboration (Ayuso et al., 2006; Goodman et al., 2017), embedding it in the open innovation perspective (Dahlander & Gann, 2010). For discussions on *open innovation strategy* (Bader & Enkel, 2014; Chesbrough & Appleyard, 2007) our results imply that firms' capabilities matter to a great extent regarding whether focal firm-specific benefits are achieved, but this is partially contingent on the firm's internal and external features. In our post hoc-analyses we found that a there is high variety in the profiles of firms conducting SOI. Some firms innovative incrementally in sustainability space and benefit from coordinating a stable network of alliances, while other firms find also benefits from

tapping into new alliance partners in search for radical knowledge combinatiosn and resulting SOI outcomes. However, we also found a segment of firms that are highly innovative but benefits less from alliances, perhaps due to their internal R&D efforts. Therefore, it is important to view open innovation strategy in sustainability contexts as a firm-specific issue, which highlights the need to achieve a strategic fit (Zajac et al., 2000) between the strategy and the firm's internal features as well as the business environment.

Second, this research contributes to expanding the current understanding of SOI (Adams et al., 2016; Jay & Gerand, 2015) by studying its connection to open innovation and alliance-management capabilities. Prior research suggests that stakeholders' collaboration is a key dimension of SOI (Ayuso et al., 2006; Ben Arfi et al., 2018; Carayannis et al., 2015; Goodman et al., 2017; Holmes & Smart, 2009). However, alliancing and, particularly, the role of alliance capabilities have not been systematically examined in the light of incremental and radical SOI outcomes. Our results provide support for earlier findings in the broader alliance and network literature that incremental developments benefit from a careful collaboration with familiar partners (and coordination among them) while a new and distant search (i.e., a proactive and entrepreneurial approach) is required for radical innovations (e.g., Enkel & Heil, 2014; Ritala et al., 2017; Rosenkopf & Almeida, 2003). By highlighting these capabilities as drivers of incremental and radical SOI, we call for more research examining the best practices and contingencies of open sustainability and collaborative SOI. Our findings validate the premise that companies exhibit better engagement in SOI by adopting an open innovation perspective (Adams et al., 2016), and that the level of SOI efforts are linked to experienced environmental turbulence (Iñigo & Albareda, 2019). In terms of further research, our model and the developed measurement approach to SOI outcomes offers conceptual tools for researchers to further examine how and why firms can improve their SOI performance.

Third, this research also contributes to alliance-management capability research by adapting and operationalizing the constructs of alliance proactiveness (Schilke & Goerzen, 2010) and alliance portfolio coordination (Sarkar et al., 2009) for the analysis of SOI. In doing so, our research further validates the process-based alliance capabilities approach proposed by Sarkar et al. (2009) and by Wang and Rajagopalan (2015), including the two main stages of pre-formation and post-formation. Furthermore, we contribute to the recent research examining the effect of these two capabilities on innovation performance (e.g., Degener et al., 2018, explaining the number of patent applications). However, our study is the first to examine these in the SOI context and in focusing on the incremental and radical dimensions of innovation. As our results show, proactiveness particularly matters for radical innovation, while portfolio coordination is more important for incremental innovation. Furthermore, radical innovation benefits from their interplay, supporting the merits of distant search and combining previously disconnected knowledge domains via alliances (Rosenkopf & Almeida, 2003; Savino et al., 2017). While these results are rather intuitive, they provide further evidence pertaining to the important question of "how firms differ" in terms of their alliance management and how and why it matters (Sarkar et al., 2009).

6.2 Managerial and policy implications

The results of this study provide several implications for managers and firms pursuing the adoption of an open innovation strategy including alliances with external partners in the SOI context. In particular, firms are likely to benefit from building and applying alliance capabilities—alliance proactiveness or alliance portfolio coordination—according to the desired SOI output. In the case of incremental innovation in a sustainability context, managers are well advised to utilize the existing alliance portfolio, find different types of complementary resources and knowledge, and combine those in the development of sustainable products, services, and processes. In the case of radical

innovation, it might be better to focus on new, disruptive partners and collaborate intensively with them on new developments.

We also identified various profiles of firms in our data, including those that focus mostly on incremental SOI, those that focus on both, as well as "super-innovators," companies that are able to adopt high levels of radical and incremental SOI and have different synergies between alliance proactiveness and alliance portfolio coordination. In practice, this suggests that our results should be linked to a profound understanding of a firm's open innovation and sustainability strategies as well as its business environment. Interestingly enough, firms representing less-innovative segments of the sample seemed to benefit more from the direct effects of alliance capabilities. This finding further highlights the relevance of developing open innovation relationships to complement a lack of internal R&D efforts, as well as in our context, the potential lack of vision regarding how to integrate sustainability issues into commercial innovation.

SOI has also become an important policy issue. The European Commission (2012) and OECD (2009) have developed policies to promote business sustainability through innovation, increasing the focus on SOI initiatives involving the use of collaboration and networks. Our results suggest that organizational capabilities that foster alliance management are indeed relevant for the development of SOIs. For that reason, policy efforts to enhance networking for SOI might usefully support capability building as well as providing more direct support for those networks.

6.3 Limitations and future research

The present study has several limitations that should be addressed in future research. The first of these relates to the sample, which was geographically concentrated in a single region where collaboration is a significant factor in innovation success (OECD, 2011). As this may have affected the results by overstating the impact of alliance capabilities on SOI outcomes, future samples might usefully include firms from different innovation ecosystems and with different characteristics in relation to alliances and networked value creation. Moreover, the cross-sectional survey design hinders causal inference as the sequence of events cannot be defined (Rindfleisch et al., 2008); for that reason, longitudinal studies could more clearly establish the relationship between alliance capabilities and incremental and radical SOI. In addition, given the understanding of incremental and radical innovation in the Oslo Manual (Eurostat and OECD, 2005), the adapted measures of SOI do not support examination of discriminant validity or construct validity. However, we used SOI as an index variable rather than for psychometric measurement of its dimensions. Further quantitative studies of SOI to develop such scales would be useful as this was beyond the scope of the present research.

Alliance proactiveness and alliance portfolio coordination are affirmed to be relevant for the pre-formation and post-formation stages of alliances (Sarkar et al., 2009). However, as additional capabilities have been identified at each stage (Wang and Rajagopalan, 2015), these may be worth studying in the future. Particularly in the open innovation context, a broader diversity of capabilities might become relevant, depending on not only the level and nature of openness in alliances but also the types of innovation outcomes pursued. In addition, we used self-reported measures for both alliance capabilities and SOI outputs, which may have led to social desirability bias (although this was alleviated by self-administration of the online version of the questionnaire and the use of forced-choice items) (Nederhof, 1985). Further research might also examine relevant capabilities at different levels of analysis (see, e.g., Wang and Rajagopalan, 2015), such as individual alliance-specific capabilities, dyadic alliance capabilities formed within the relationship, and alliance portfolio-specific capabilities. Additionally, there may be alternative ways of measuring SOI beyond the index approach adopted here; future research might, for example, examine how alliance capabilities affect SOI-

related processes, products, services, and business models. In any event, these findings should serve as a useful point of departure for further studies examining the intersection of open innovation, sustainability, and SOI.

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