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Innovation performance feedback and technological alliance portfolio diversity: The moderating role of firms' R&D intensity

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A B S T R A C T

This paper analyzes how innovation performance feedback affects firms' decisions to change the diversity of their technological alliance portfolio and how this relationship is moderated by firms' R&D intensity. In line with behavioral theory, we argue that only those firms deviating (either above or below) from their performance aspiration levels are expected to embrace changes in their alliance portfolio. We also posit that a firm's R&D intensity captures its ability to identify and detect good partners, based on its technological absorptive capacity. On this basis and given that recent innovation performance may condition firms' attractiveness as partners, we expect that for firms performing below aspirations, R&D intensity negatively moderates the propensity to increase alliance portfolio diversity. On the contrary, when firms perform above aspirations, R&D intensity reinforces the propensity to increase alliance portfolio diversity. We find support for our hypotheses based on data from the Spanish Technological Innovation Panel from 2008 to 2015.

1. Introduction

Survival in technology-intensive industries is highly dependent on the firms' ability to acquire and develop new capabilities and technological knowledge (Pisano, 1990). In this sense, and given the high dynamism of today's competitive environment, technological alliances have become a good vehicle to access the required external knowledge to improve innovative performance and keep the competitive edge (Ahuja, 2000a; Belderbos et al., 2004; Hagedoorn 2002; Martínez-Noya and Narula 2018). For the purposes of this paper, technological alliances are considered as relationships in which partners actively cooperate for technological innovation. In relation to these collaborations, one important decision is the selection of relevant partners (Nieto and Santamaría, 2007). Firms can cooperate with customers, competitors, suppliers, or universities both at the domestic and/or international level. Each type of partner offers the possibility of accessing different types of external knowledge, contributing differently to innovation performance (Ashok et al., 2016; Belderbos et al., 2006; Un et al., 2010). Thus, cooperation with a diverse portfolio of partners has been found to lead to knowledge complementarities and synergistic effects improving innovation performance (Jiang et al., 2010; van Beers and Zand, 2014), especially in periods of technological turbulence (de Vaan, 2014). Nevertheless, increasing partner diversity also entails some degree of uncertainty and risks, generating higher managerial costs due to increased communication, coordination, and monitoring problems (Goerzen and Beamish, 2005; Lee et al., 2017). Furthermore, these risks are expected to be even greater in technological cooperation due to the tacitness and location-specific nature of this high-valued adding activity (Martínez-Noya and García-Canal, 2018; Monteiro et al., 2017). Therefore, firms face trade-offs when considering changes in the diversity of their alliance portfolio (Duysters and Lokshin, 2011; Jiang et al., 2010). Given the potential benefits but also risks, ample research on alliance management has focused on analyzing firms' motivations to form technological alliances (Mowery et al., 1998) or addressing the performance consequences of increasing alliance portfolio diversity —see Lee et al. (2017) for a review. However, much less studied has been the role that performance feedback may play when dealing with this portfolio diversity trade-off (Gavetti et al., 2012). This research gap is especially relevant if we consider that performance feedback studies provide a realistic view of how firms make change decisions.

Given this research gap, in this paper we analyze the following research question: does innovative performance feedback (positive or negative) increase technological alliance portfolio diversity? This is an important research question for the fields of strategic management and R&D policy, not only because of the high failure rate of R&D alliances or the trade-off between technological complementarities and risks that

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exists when increasing alliance diversity, but also due to the importance of considering how each type of feedback might influence changes in alliance diversity. To address this research question, we build on the behavioral theory of the firm. This theory posits that discrepancies between performance aspirations and actual performance trigger organizational change, although in a different way depending on the firm's relative performance as compared to its aspiration level (Cyert and March 1963; March 1991, 1994). If performance is below aspirations, firms are expected to embrace problemistic search to find a solution to this problem. If performance is above aspirations, firms may be motivated to embrace slack search to explore new value creation opportunities. It should be noted that, although most research in the behavioral theory of the firm has focused on analyzing the role of financial performance measures (such as return on assets or market share) on firm's decisions (de Leeuw et al., 2019; Greve, 2003a, 2003b; Baum et al., 2005; Iyer and Miller, 2008; Posen et al., 2018), in this paper we apply this theoretical logic to a non-financial performance measure such as innovation performance (measured through patents) for firms in technology-intensive sectors. This is so because, for these firms, innovation goals may precede financial goals, as staying competitive in these industries is all about keeping innovative activities on the right performance track (Tyler and Caner, 2016).

Therefore, based on this logic we expect that the more distant firms are to their innovation performance aspiration levels, the more likely they will increase their alliance partner diversity with the intention of either accessing new technological knowledge to close the performance gap (for those performing below aspirations), or to explore new technological opportunities beyond their existing network (for those performing above aspirations). In addition, we expect that these effects of performance feedback on alliance portfolio diversity will be moderated by a firm's R&D intensity. Other things being equal, we consider that firms having a higher R&D intensity will have developed a higher technological absorptive capacity (Bertrand and Mol 2013; Cohen and Levinthal, 1989, 1990; Giuliani and Bell, 2005; Laursen and Salter, 2006) that allow them to be better prepared to calibrate the expected gains from possible new partners as well as anticipate the costs of new collaborations (Mayer and Salomon, 2006). Therefore, we posit that depending on their ability to attract partners based on their recent innovation performance (Ahuja, 2000b; Blind et al., 2006; Kim and Rhee, 2017) they will be willing or not to increase the diversity of their alliance portfolio. More specifically, we expect that for firms performing below aspirations, R&D intensity will reduce their propensity to increase alliance portfolio diversity. On the contrary, for firms performing above aspirations, we expect R&D intensity to positively moderate this relationship.

We find support for our hypotheses using data from the Spanish Technological Innovation Panel (TIP), Spain's contribution to the European-wide Community Innovation Survey (CIS), for firms operating in technology-intensive sectors for the period 2008–2015. Given that we theoretically develop and empirically show that innovation performance feedback influences firms' decision to embrace changes in the diversity of their technological alliance partners, our paper makes several contributions. Our findings contribute to the alliance management literature by showing that innovation performance feedback (either below or above aspirations) is another important reason to change the diversity of an alliance technological portfolio. Our results likewise extend behavioral research by demonstrating that innovation goals are also important to be acknowledged as key drivers of organizational change. Our study is thus aligned with a recent branch of behavioral theory that has started to acknowledge how innovation performance feedback can influence firms' R&D decisions, such as Tyler and Caner's (2016) study on alliance formation; Lungeanu's et al. (2016) paper on technology-sourcing vehicles; Kavusan and Frankort (2019) on alliance portfolios; or the one by Gaba and Bhattacharya (2012) on the creation of corporate venture capital units for conducting R&D. Finally, while analyzing different boundary conditions becomes critical to understand why studies can find conflicting results on organizational responses to performance feedback (see Kotiloglu et al., 2021 for a meta-analytic review); behavioral studies have traditionally not paid too much attention to the boundary conditions of the relationship between behavioral drivers and organizational decisions (Greve and Gaba, 2017; Shinkle, 2012). We add to this literature by showing how a firm's R&D intensity moderates the relationship between performance and the decision to change alliance portfolio diversity. To the best of our knowledge, ours is the first study showing that R&D intensity, considered as a measure of absorptive capacity, is a boundary condition that interacts with behavioral mechanisms to explain organizational change.

2. Theoretical background

2.1. Innovation and performance feedback in technology-intensive industries

One of the building blocks of the behavioral theory of the firm (Cyert and March 1963) is that firms avoid uncertainty. This means that firms do not cope with uncertainty by building elaborate long-term plans. Instead, they manage uncertainty by making short-run adjustments to short-run performance feedback and by arranging a negotiated environment through agreements with interdependent organizations (Cyert and March 1963). In this way, discrepancies between performance aspirations and actual performance trigger organizational change, although in a different way depending on the firm's relative performance as compared to its aspiration level (Cyert and March 1963; March 1991, 1994). Behavioral theorists argue that performance aspirations are contingent on a firm's own historical performance as well as on the average performance of their peers, and evolve over time acting as reference points for managers in terms of what can be considered firms' successes or failures (Bromiley and Harris, 2014; Greve, 2003a, 2003b; Levinthal and March 1981). As the outcomes of organizational change are uncertain and involve some risks, this approach argues that firms would have a different attitude towards change depending on whether they are performing below or above aspirations (Greve 2003a; March and Shapira, 1987). If performance is below the aspiration level, firms embrace change through problemistic search (Cyert and March 1963), increasing the intensity of organizational search and change in order to get the firm back on the right performance track,[1] even if this entails taking risks (Greve 2003a). If performance is above the aspiration level, actions that can place the firm below the aspiration level would be avoided (Cyert and March 1963; March and Shapira, 1987) and as firms go above aspiration levels they can embrace change by dedicating more resources to slack search, i.e. "extra time and resources that are used for experimentation" (Greve 2003b, p.54).[2] Whereas problemistic search is aimed at finding a solution to a specific short-term problem, slack search is associated with projects of an exploratory nature and with the availability of tangible and/or intangible resources to embrace them.

Although it is well known that firms pursue a wide range of financial and non-financial conflicting goals, and behaviors are guided by different aspirations (Gaba and Greve, 2019; Locke and Latham, 1990), most research in the behavioral theory of the firm has focused on analyzing the role of financial performance measures (such as return on assets or market share) on firm's decisions (Greve, 2003a, 2003b; Baum et al., 2005; Iyer and Miller, 2008; Posen et al., 2018). Nevertheless, considering the impact of other non-financial performance measures on firms' decisions should be also important because decision-makers may

[1] In words of Cyert and March (1963: 121) problemistic search means "search that is stimulated by a problem… and is directed toward finding a solution to a problem". For a recent summary of empirical findings for problemistic search see Posen et al. (2018).

[2] Cyert and March (1963: 279) refer to this kind of activities as "projects that would not necessarily be approved in a tight budget."

pursue different goals in a sequential way based on salience (Gaba and Greve, 2019; Greve, 2008). This means that due to the causal linkages that exist among goals, the accomplishment of one goal may contribute to the fulfillment of the next one (March and Simon, 1958). This is especially the case for technology-intensive sectors, for which innovation goals may precede financial ones. Staying competitive in these industries is all about keeping innovative activities on the right performance track, because if innovation objectives are not accomplished, financial performance ones are not expected to be met either (Tyler and Caner, 2016). This is so because in these R&D intensive industries, the firm's ability to develop a continuous stream of innovations can be critical to create and sustain its competitive advantage (Brown and Eisenhardt, 1995; Rosenbloom and Christensen, 1994; Pisano, 1990) as well as to access attractive investors in case they need founding (Baum et al., 2005). Consequently, even though it has been shown that in the case of ambiguity between financial and non-financial performance feedback organizational responses may be impacted (Joseph and Gaba, 2015), it can be argued that in these industries current financial performance may not be the best indicator of future performance (Lungeanu et al., 2016).

For this reason, in technology-intensive industries firms are expected to make short-term adjustments to their technology strategy in response to their short-run innovation performance feedback. Given that a critical part of the technology strategy that can be adjusted in the short term is the composition of the portfolio of technological partners (Baum et al., 2005), in this paper we add to the behavioral theory of the firm by analyzing how firms adjust the diversity of their technological alliance partner portfolio as a response to their innovation performance. As an indicator of firm innovation performance, we consider the patenting activity of a firm relative to its aspiration level, which is consistent with previous research assessing performance feedback in technology-intensive industries (Gaba and Bhattacharya, 2012; Kavusan and Frankort, 2019; Lungeanu et al., 2016; Tyler and Caner, 2016).[3]

2.2. Alliance portfolio diversity and innovation performance

Previous research has shown that a critical factor that determines a firm's ability to innovate and compete in a technology-intensive industry is the composition of its technological sourcing portfolio (Lungeanu et al., 2016; Van de Vrande, 2013; Veugelers and Cassiman, 1999). In this way, firms manage their alliances with a portfolio perspective, seeking to maximize resource and learning benefits by collaborating with a variety of partners while at the same time minimizing the associated managerial costs (Asgari et al., 2017; Kavusan and Frankort, 2019). Although not in all domains, alliance portfolio diversity has been found to have a positive effect on performance (García-Canal and Sánchez-Lorda, 2007; Lee et al., 2017). For this reason, we expect that firms may decide to modify their technological partner portfolio diversity in response to innovative performance feedback either by adopting changes oriented towards focusing on exploiting existing resources, or by exploring new ones (March 1991).

For the purposes of this paper, we will consider two dimensions of partner diversity: first, organizational diversity (types of organizations with whom the firm allies) and, second, national diversity (in terms of geographical areas of origin of the firm's partners). These two alliance dimensions are important for innovation because alliances can be formed with different types of organizations (i.e. suppliers, competitors, universities, public institutions…), and each type offers different pools of resources and capabilities, increasing a firm's breadth of search (Harrison et al., 2001). Indeed, in the specific case of technological alliances, each type of organizational partner differs in terms of the breadth of new knowledge provided to the firm and in the ease of access to this new knowledge, resulting in a different impact on product innovation (Nieto and Santamaría, 2007; Rodríguez et al., 2017; Un et al., 2010). In addition, firms may opt to incorporate in their alliance portfolios partners from different countries, as geographically distant partners can provide access to location-specific complementary capabilities (Lane et al., 2001) and are more likely to be sources of diverse knowledge that can enhance innovation performance (Berchicci et al., 2016; Rodan and Galunic 2004). Therefore, in both cases, increasing the diversity of technological partners grants the firm access to fresh perspectives to enrich its innovation projects.

Nevertheless, it should be noted that despite the already mentioned knowledge and resource access advantages that both organizational and national diversity can offer to a firm's alliance portfolio, increasing partner diversity also entails higher managerial costs and, thus, risks (Goerzen and Beamish, 2005; Kobarg et al., 2019; Lee et al., 2017). This is so because different types of organizations tend to differ on their strategic orientations, processes, and systems, which may increase managerial costs due to communication and coordination problems (Estrada et al., 2016; Jiang et al., 2010; Martínez-Noya et al., 2013). Similarly, allying with partners from different countries also increases managerial costs due to the tensions that arise because of differences in their corporate cultures or institutional contexts that can make the transfer and protection of the knowledge more difficult (Lavie and Miller, 2008; Martínez-Noya and García-Canal, 2018; Teece, 1986; Parkhe, 1991; 1993). Indeed, given these trade-offs, it is not surprising that previous literature lacks conclusiveness on the effects that alliance portfolio diversity has on performance (Lee et al., 2017). Moreover, in the case of technological alliances —and particularly in R&D intensive industries—, all the previous risks resulting from increasing alliance partner diversity are expected to be especially high. This is due to the strategic value of R&D activities (Mudambi, 2008) that usually require the transfer of firm-specific and tacit knowledge (Cantwell and Santangelo, 1999) —i.e. knowledge that includes hard-to-communicate skills or know-how. This type of knowledge is difficult to protect (Narula, 2001), especially when the alliance involves countries offering poor intellectual property protection rights (Oxley, 1999). This means that technology-intensive firms need to adopt in each location the right degree of openness of their R&D processes to external partners to benefit from external knowledge while protecting their proprietary one (Gooris and Peeters, 2016; Mudambi et al., 2018; Pisano, 2006; Santangelo et al., 2016); something that increases in difficulty the more diverse the firms' alliance portfolio is. Consequently, if not properly managed, establishing more diverse alliances may harm the innovative performance of the firm and/or its competitive position. In addition, the inclusion of novel partners may generate defensive responses from existing partners that may see this action as a signal of distrust and less attention and resources allocated to their previous collaborations (Singh and Mitchell, 1996).

In conclusion, given the trade-off that exists between benefits and costs when adding new categories to the R&D alliance portfolio and the fact that firms are heterogeneous in their attitudes towards risk (Cyert and March 1963; March 1994; March and Shapira, 1987), we take a behavioral perspective to analyze how firms deal with these trade-offs when their innovation performance deviates from their aspiration levels. The essence of our argumentation is that firms that are in their innovation performance aspiration level, or just very close to it, will be unwilling to adopt any major organizational change like increases in technological alliance portfolio diversity due to uncertainty avoidance and to the satisficing criteria associated with bounded rationality (Cyert and March; 1963; March and Shapira, 1987; March and Simon, 1958; Greve 2003b). However, as we will explain below, deviations from their aspiration levels may make firms more open to overcome their

[3] As explained by Hagedoorn and Cloodt, (2003), despite some criticism in the use of patents as a performance indicator by some authors, they are generally accepted as one of the most appropriate indicators that enable researchers to compare the innovative performance of firms— in terms of new technologies, new processes and new products—, especially in the context of many high-tech industries.

uncertainty avoidance and embrace changes in their alliance portfolios, although driven by two completely different underlying motivations.

2.3. Innovation performance below aspirations

According to behavioral theory, when performance is below aspirations firms may initiate problemistic search, which leads them to embrace changes in an attempt to resolve the performance gap (Cyert and March 1963). Even though problemistic search initially starts by focusing on local search practices —for example, redefining some organizational practices prevalent in the subunit most closely related to the performance shortfall (Greve, 2003; Levinthal and March 1993)— it later moves towards stimulating non-local search and exploration, looking for solutions to problems in other subunits within the firm or even in external organizations (Baum and Dahlin, 2007; Cyert and March 1963). This is so because the further a firm's performance is below its aspirations, the lower the probability of achieving acceptable performance through minor adjustments. Instead, the firm will need to focus on non-local solutions and riskier decisions offering the possibility of at least improving the firm's performance to its aspiration levels (Baum et al., 2005).

In the specific case of technology-intensive firms, in a situation of poor innovation performance (i.e. patents below aspirations) firms may start by adopting local search actions —such as modifying the resources allocated to in-house R&D or revising R&D project evaluation criteria. These local search reactions to performance feedback may vary depending on who is the decision maker —i.e. managers of business units or managers of corporate offices— (Gaba and Joseph, 2013). However, as the performance gap increases, firms may start searching for non-local solutions to problems such as forming new R&D alliances (Tyler and Caner, 2016). Given that R&D alliances are often used to access solutions to new product development problems, and as a means to create future new product opportunities (Gilsing and Nooteboom, 2006; Grant and Baden-Fuller, 2004; Katila and Ahuja, 2002; Teece, 1992), we expect that firms will be more open to embrace changes in their technological alliance portfolio by incorporating more diverse partners as innovation performance falls below aspiration levels. Due to technological dynamism, firms in technology-intensive industries face many difficulties in developing and maintaining the multiple technological competencies required (Singh and Mitchell, 1996). In this context, a new partner bringing complementary external knowledge and fresher perspectives may be the recipe to improve the current disappointing technological performance to catch-up. This is so because this alliance portfolio reconfiguration can enable the firm to expand the number of technological resources available as well as to experiment with innovative ways of combining resources (Kavusan and Frankfort, 2019), creating more innovation opportunities (Vassolo et al., 2004). Therefore, despite the possible risks of incorporating more diverse and unfamiliar partners, we expect that as firms perform below their innovative aspiration level, they will be more willing to embrace these changes in an attempt to restore the expected performance. In other words, we expect that:

H1. . The more a firm performs below its innovative aspiration levels, the more likely the firm will increase its technological alliance portfolio diversity.

2.4. Innovation performance above aspirations

As firms perform better than expected, they are more willing to engage in slack search, which may also lead to experimentation and organizational change (Cyert and March 1963). Indeed, firms accumulate slack resources as performance rises above aspirations (Levinthal and March 1981), so slack search is most likely to be adopted by firms that have persistent positive performance discrepancies (Chen and Miller, 2007). More specifically, previous literature has found that experimentation by firms performing above aspirations is driven by their better access to additional resources or the possibility of accessing them at a lower cost, as well as by the extra confidence gained by managers that might make them more willing to pursue promising ideas that were previously considered too risky (Cyert and March 1963; Singh, 1986; Nohria and Gulati, 1996). Therefore, as firms move above the expected aspiration level, they become less concerned by the dangers and risks of new projects and become more open to experimentation and exploration (March and Shapira, 1987); not because they are more motivated to assume those risks, but mainly because they have a higher capacity for risk taking (Xu et al., 2019). In these cases, besides the slack resources that may have been generated by past performance, the increased distance between actual and aspiration performance acts as a buffer against the loss of the positive track and thus leads their confident managers to adopt non-local explorative actions, such as the initiation of riskier non-local alliances in an attempt to achieve an even greater gain (Baum et al., 2005; March and Shapira, 1992). In fact, alliances are a means to reduce uncertainty from the environment, creating what Cyert and March (1963) call a "negotiated environment", by which firms can secure access to external resources from their partners.

Based on this, for the specific case of technology-intensive firms, we expect that the further a firm's innovative performance is above its aspirations, the higher its chances to successfully engaging in slack search by incorporating more diverse partners in their alliance portfolio in an attempt to find new opportunities to exploit their technologies in new fields, or to undertake R&D projects with higher risks but also higher potential payoffs (Baum et al., 2005; Chen and Miller, 2007). As explained before, firms in this type of industries face great difficulties in developing and maintaining in-house all the required technological competencies to keep their competitive edge. Therefore, they may benefit from partnering with more diverse organizations. In addition, the more a firm is patenting above its aspirations, the more it can be expected to be in the technological frontier in their field (Ahuja, 2000b; Hagedoorn and Cloodt, 2003; Rothaermel and Boeker, 2008), which means that even in the case that they may not have enough internal slack resources to embrace organizational change, this may not be a problem. These firms are expected to get access to new and better resources at a lower cost because of their capacity to attract better investors or alliance partners to continue developing their research projects (Baum et al., 2005). In this sense, it should be noted that although having an outstanding patenting track does not necessarily imply having excess financial resources, patent activity is immediately visible to other companies, which means that firms with a valuable patent stock are in an excellent condition to negotiate alliances in favorable terms (Bosse and Alvarez, 2010), so they can easily engage in slack search activities irrespective of their current financial situation. Taken together, all this suggests that the more a firm performs above its innovation aspirations, the more confident their managers will be in exploring new technological projects that otherwise would not be considered, as well as the less costly it will be for them to attract new partners offering complementary resources. For these reasons, we expect that, as far as these cooperative projects do not put at risk the favorable position of the firm, these new opportunities will be explored creating a negotiated environment through which high performing firms will try to secure access to future innovations, and/or keep the innovative edge. Thus, we hypothesize that:

H2. . The more a firm performs above its innovative aspiration levels, the more likely the firm will increase its technological alliance portfolio diversity.

2.5. The moderating effect of R&D intensity

Previous research on the behavioral theory of the firm shows that both problemistic search and slack search may lead firms to make risky choices (Baum et al., 2005). However, firms are only expected to make these choices when there is a clear means-end relationship between the choice and the desired goal (Greve 2003b). In the absence of this certainty, for instance because not all possible outcomes or their probabilities can be specified ex-ante, uncertainty avoidance would make these firms reluctant to make these changes (Cyert and March 1963; Greve 2003b). With this in mind, it is clear that the previously formulated hypotheses can be nuanced if we take into account firms' heterogeneity in the assessment of technological alliances. It is well known that firms need to be able to effectively leverage their dispersed resources to fully realize potential synergies in their alliance portfolios (Gulati et al., 2011; Sarkar et al., 2009), especially in innovation contexts. However, this leverage can be hampered not only by firms' heterogeneity in their risk-taking behavior, but also by heterogeneity in their risk assessment capabilities. Not all firms are equally prepared to assess the risks and returns of technological alliances as they differ in their technological expertise due to their previous R&D efforts (Laursen and Salter, 2006).

Cohen and Levinthal's (1989) classic paper on the two faces of R&D clearly showed that, besides generating innovations, firms conduct R&D activities to "identify, assimilate, and exploit knowledge from the environment" (1989, p. 569), developing an absorptive capacity based on their previous R&D efforts (Cohen and Levinthal, 1990). Furthermore, these R&D efforts, measured through a firm's R&D intensity (a firm's R&D expenses divided by its sales), appear to be especially critical when a firm wants to acquire and use knowledge that is unrelated to its ongoing activity (Cohen and Levinthal, 1990), something that may be likely to happen when incorporating more diverse technological partners. Previous research has shown that firms that spend more on R&D have a higher propensity to cooperate in R&D (Cassiman and Veugelers, 2006); establish more linkages with external sources of knowledge (Giuliani and Bell, 2005); have higher chances of success in their cooperative projects (Lhuillery and Pfister, 2009); and tend to form alliances with firms with the same degree of R&D intensity (Yayavaram et al., 2018). Taken as a whole, this evidence shows that previous R&D investments contribute to developing firms' absorptive capacity by preparing them to better identify which the best partners are, manage the contractual hazards associated with these collaborations, and thus be able to extract the maximum value from them.

On this basis, we expect that firms with high levels of R&D intensity will be better able to identify and exploit external sources of knowledge (Laursen and Salter, 2006; Bertrand and Mol, 2013). Indeed, according to Hashai and Almor (2008), since R&D intensity captures the firms' willingness to invest in the creation and absorption of technical knowledge, these investments are key to the firms' ability of firms to appropriate value from this knowledge. Therefore, we expect firms' R&D intensity to moderate the effect of innovation performance feedback on the firms' likelihood of increasing its alliance partner portfolio diversity. This is so because we expect that the higher the firm's R&D intensity, the more the accumulated technological absorptive capacity. Thanks to this technological absorptive capacity, the firm can assess the potential of prospective partners and manage the contract effectively by an adequate evaluation, and management, of both the returns and risks associated with the alliance. Ample evidence suggests that firms with high R&D intensity are more willing to cooperate and/or get the most of their alliances. For instance, Bertrand and Mol (2013) found that firms with higher R&D intensity are more willing to outsource offshore, while Berchicci et al. (2016) and Xie et al. (2019) found that firms with higher R&D intensity obtained more innovative results from their collaborations. In this way, our expectation is aligned with previous research that has found a moderating effect of absorptive capacity on the effectiveness of external knowledge sourcing (Escribano et al., 2009; Rothaermel and Alexandre, 2009; Tsai, 2009).

Based on this, we contemplate the following four scenarios for the moderating role of R&D intensity, which we capture in Fig. 1. The figure shows a 2 × 2 matrix based on two dimensions: (i) R&D intensity and (ii) relative innovation performance to aspirations levels. As already mentioned, R&D intensity is considered an indicator of the firm's ability

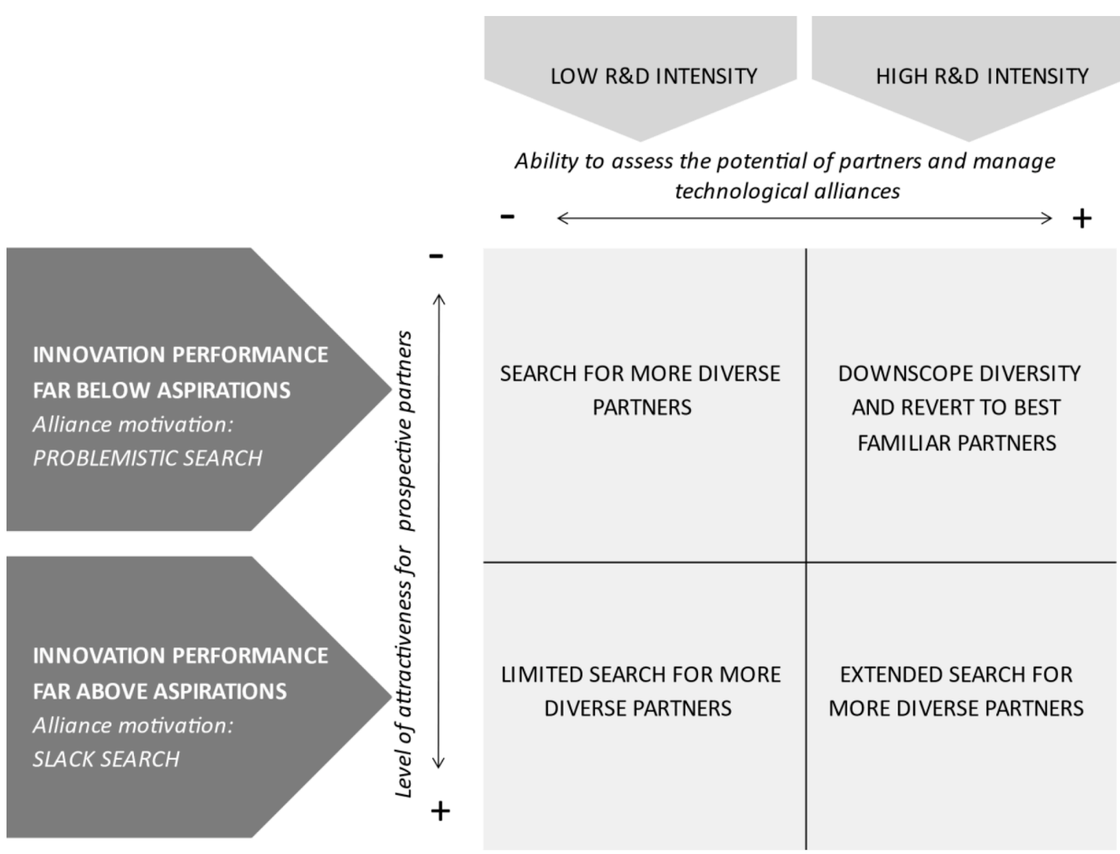

Fig. 1. Effects of innovation performance feedback and R&D intensity on technological alliance portfolio diversity.

to identify the potential of partners and to assess and manage the associated risks (Cohen and Levinthal, 1989). Relative innovation performance is associated with the firms' degree of attractiveness for external partners. We consider that it is important to consider this second dimension because not all firms are expected to attract partners in the same way. Although firms can have strong motivations to change their alliance portfolio diversity, they may not have good opportunities to do so because not all firms are equally attractive as partners (Kim and Rhee, 2017), so the best possible partners may not be willing to work with them. In this way, we consider that firms' recent innovative performance (patenting activity) can be considered a good indicator of their attractiveness (Ahuja, 2000b) because, as found by Blind et al. (2006), firms patenting activity improves a firm's position in negotiations with partners and acts as a reputational signal.

We expect that when innovative performance falls below aspirations, R&D intensity will negatively moderate the firm's propensity to increase its technological alliance portfolio diversity. The firm's level of technological absorptive capacity due to prior R&D efforts will help it to more effectively identify the real potential contribution of not only incorporating more diverse partners, but also the contribution of the familiar ones. In this context, we posit that the poor recent observable performance of the firm is not expected to attract the best, but only equally underperforming firms, which would be discarded as valid partners thanks to the firm's technological absorptive capacity. This is so for two reasons. First, the more R&D intensive the firm is, the more it is going to realize that the possible new available partners are not likely to get the firm back on the right performance track. And second, the firm is going to be able to better assess the problems that may exist in its alliance portfolio and thus identify which of its partners should be discarded. Therefore, we expect that problemistic search in these cases would lead the more R&D intensive firms to reconfigure their existing alliance portfolio by downscoping it, keeping only the current successful alliances, maintaining, or even reducing their alliance diversity. Indeed, previous studies have also shown that, although performance below aspirations tends to motivate problemistic search and risk taking, under some circumstances it can also increase reliance on more conventional and well-learned responses leading firms to remain focused on preexisting routines and not experimenting with new strategies (Gaba and Bhattacharya, 2012; Gilbert 2005; Ocasio, 1995). This can be explained because, as previously shown by behavioral economists (Kahneman and Tversky, 1979, 1984; March and Shapira, 1987), the propensity to embrace risks in unfavorable environments only appears when the risky action has some chances of reverting the negative situation. On the contrary, we expect that the lower the R&D intensity of the underperforming firms, the less able they will be to identify the problems that may hamper the effectiveness of the alliances in terms of the adequacy of the new more diverse partners and the possible conflicts and problems of coordination that may appear. These companies would not be able to discard the fact that these alliances cannot put the company back on the right performance track and would also have a lower ability to reconfigure their current portfolio of alliances. As a result, we hypothesize that:

H3. . When a firm's innovative performance falls below aspirations, R&D intensity decreases the propensity to increase technological alliance portfolio diversity.

In contrast, we expect that when innovative performance rises above aspirations, R&D intensity positively moderates the firms' propensity to increase their technological alliance portfolio diversity. In these cases, we expect that a firm's level of technological absorptive capacity due to prior R&D efforts will help it to more effectively identify the available innovation value creation opportunities that can result from incorporating more diverse partners and manage the difficulties of increasing the diversity of its alliance portfolio. This is so for two reasons. First, the further the firm is performing above expectations, the higher will be its bargaining power for new alliances (Blind et al., 2006) and so will be its level of attractiveness for new partners (Ahuja, 2000b), so interesting partnering opportunities will arise. And second, the higher the R&D intensity of these high performing firms, the higher the expected performance of these partnering opportunities, because they would be better prepared to manage the risks associated with increased levels of alliance portfolio diversity. As pointed out by Baum et al. (2005), high performers are expected to be able to attract the best partners while incurring lower costs. In fact, having a positive innovation performance track coupled with a high R&D intensity constitutes the best scenario to create a negotiated environment with the best partners available, paving the way for a leading position in the race for future innovations. On the contrary, firms performing above aspirations but with lower R&D intensity will be ill-prepared to select the best partners and to make the most of these agreements, so they will be less likely to enter a virtuous circle of continuous innovation. In other words, the higher the R&D intensity, the more capable the firm will be to identify and select the best new partners and reduce the risks of losing its innovating edge close to zero when initiating partnerships with more diverse partners. As a result, we hypothesize that:

H4. . When a firm's innovative performance rises above aspirations, R&D intensity intensifies the propensity to increase technological alliance portfolio diversity.

3. Methods

3.1. Database

The data for this study come from the Spanish Technological Innovation Panel (TIP) (Panel de Innovación Tecnológica, PITEC, in Spanish) which is built upon the annual Spanish responses to the European-wide Community Innovation Survey (CIS). The Spanish National Statistical Institute (INE) collects these data on a yearly basis in association with the Spanish Science and Technology Foundation (FECYT) and the Foundation for Technological Innovation (COTEC). The survey applies the methodological guidelines defined by OECD's Oslo Manual and offers highly representative and detailed data on the technological innovation activities of Spanish firms from all sectors. In this panel, firms are observed repeatedly on a yearly basis since 2003. Therefore, TIP provides a very rich dataset for analyzing our research question on the evolution of innovation alliance portfolios because we have information on both cross-sectional differences between firms and temporal changes within each firm. In addition, as previous studies have shown, Spain provides a good empirical setting to test our hypotheses because its industrial structure is very similar to the one of other countries in the EU and it occupies a middling position in the technological arena (e.g. Chapman et al., 2018; Coad et al., 2016; Cuervo-Cazurra et al., 2018; Cuervo-Cazurra and Un, 2009; Rodriguez et al., 2017).

For the purposes of our study and given the different propensity to innovate and to patent that exists across industries we chose to narrow our panel to Spanish non state-owned firms operating in those industries considered as being of medium to high technological intensity according to the OECD (OECD, 2011).[4] Indeed, it is well known that, contrary to what happens in low-tech sectors, alliances are expected to play a more critical role for innovation within technology-intensive industries (Arora et al., 2008). As a result, we use an unbalanced panel with more than 6500 firms for the period from 2008 to 2015.

3.2. Variables

3.2.1. Dependent variable

In the questionnaire each year firms are asked to indicate with whom of the following partners they actively engaged in cooperation for

[4] See the industries included in table 1.

technological innovation[5]: (1) other firms belonging to the same group, (2) suppliers, (3) clients, (4) competitors, (5) commercial labs, (6) universities and (7) technological research centers. In addition, for each type of the previous alliance partners, firms have to indicate their geographical location, being the options: (1) its country of origin (in this case, Spain), (2) other EU country, (3) the US, (4) China or India, and (5) other countries. Based on this information, we calculated our dependent variable (ALLIANCE PORTFOLIO DIVERSITY) as the count of the different partner-location combinations that a firm had each year, being the maximum number of possible combinations 35 and the minimum 0. Therefore, our unit of observation is the firm-year. We obtained 21,657 observations for our dependent variable with a minimum value of 0 (with a frequency of 13,719 observations, 63.35% of the sample) and a maximum value of 27 (see table 1).

3.2.2. Independent variables

Consistent with previous research assessing performance in technology-intensive industries, to capture firms' innovation relative performance we consider the patenting activity of a firm relative to its aspiration level (Gaba and Bhattacharya, 2012; Kavusan and Frankort, 2019; Lungeanu et al., 2016; Tyler and Caner, 2016). As previous studies have shown, patents represent externally validated measures of innovative success, especially in technology-intensive industries (Ahuja, 2000b; Hagedoorn and Cloodt, 2003), as in these industries firms that patent more than their peers are considered to be in the innovation frontier of their field (Rothaermel and Boeker, 2008). In fact, in these industries, patents have been found to be closely related to sales growth, expert ratings of technological strength, new product introductions and inventions (Ahuja and Katila, 2001). Therefore, we measured the firms' actual technological innovation performance for a given year (P) as the number of patent applications made by the firm over a three-year window (i.e. from *t* to *t-2*). Given this patent data, we followed these steps to calculate our variables related to the firm's innovation performance above or below aspiration levels. First, consistent with prior research (Cyert and March 1963; Greve, 2003; 2008; Yang et al., 2017), we computed firms' aspiration levels (A) as a mixture of its social aspiration (SA) and its historical performance aspiration (HA). The social aspiration level (SA) reflects the performance of the social reference group that the focal firm attempts to anchor, and it is computed as the average of the patenting activity of the other firms in the same sector for the same period t. The historical aspiration level (HA) captures the focal firm's past technological innovation performance as an indicator of how well it should perform, and it is composed of the previous-year historical aspiration level and the previous-year technological innovation performance. The equations read as follows, where *t* is time and *i* indicates the firm:

Table 1
Composition of the sample.

ALLIANCE PORTFOLIO DIVERSITY	N	Percent	INDUSTRIES	N	Percent
0	13,719	63.35	Machinery and equipment	4668	16.94
1	2623	12.11	Chemicals	4003	14.52
2	1530	7.06	Fabricated metal products	3906	14.17
3	1134	5.24	Rubber and plastics products	2491	9.04
4	751	3.47	Other non-metallic mineral products	2094	7.6
5	507	2.34	Computing machinery, precision and optical instruments	1907	6.92
6	373	1.72	Motor vehicles	1851	6.72
7	287	1.33	Electrical machinery and apparatus	1835	6.66
8	214	0.99	Other transportation	1476	5.36
9	127	0.59	Pharmaceuticals	1102	4
10	118	0.54	Basic metals	1087	3.94
11	60	0.28	Installation and repairing of machinery and equipment	605	2.19
12	37	0.17	Other transport equipment	211	0.77
13	37	0.17	Building of ships and boats	157	0.57
14	35	0.16	Aircraft and spacecraft	149	0.54
15	28	0.13	Petroleum	21	0.08
16	19	0.09	Total	21,657	100
17	20	0.09			
18	11	0.05			
19	5	0.02			
20	1	0			
21	5	0.02			
22	6	0.03			
23	3	0.01			
24	4	0.02			
25	1	0			
26	1	0			
27	1	0			
Total	21,657	100			

$$A_{ti} = a_1 SA_{ti} + (1 - a_1) HA_{ti}$$

$$HA_{ti} = a_2 HA_{t-1,i} + (1 - a_2) P_{t-1}$$

Since there is no consensus about how firms weigh their performance when determining their aspiration levels (Bromiley and Harris, 2014), we followed Greve (2003a) and we estimated the weights by searching all parameters values by increments of 0.1 and we selected the combination offering the best fit. As a result, 0.5 for a_1 and 0.4 for a_2 were the values that provided the best fit of the models to the data. Consistently with previous research, in our model the most recent performance (P) is weighed higher than HA in *t-1* (Chen, 2008; Tyler and Caner, 2016).

Finally, to test for a different effect on alliance partner diversity for firms performing above or below their innovative aspiration levels, aligned with previous performance feedback studies, we computed the distance to the aspiration level (DA), defined as the value of the difference between the firm's actual innovation performance (P) at *t* and its aspiration level (A) at *t*: ($DA_{ti} = P_{ti} - A_{ti}$). According to previous research (Baum et al., 2005; Greve, 2003a, 2003b) and based on Greene (1993: 235–238), we implemented a spline function for performance so that we entered separate variables for performance above and below aspiration level. Therefore, our variable INNOVATION PERFORMANCE ABOVE ASPIRATIONS (PAA) equals 0 for all observations in which $DA<0$, and the distance to the aspiration level otherwise. Symmetrically, INNOVATION PERFORMANCE BELOW ASPIRATIONS (PBA) equals 0 for all observations in which $DA>0$, and the distance to the aspiration level otherwise. In our estimations, we reverse-coded INNOVATION PERFORMANCE BELOW ASPIRATIONS for ease of interpretation of our interaction variables, so its values are always positive.

To capture the moderating effect of R&D intensity on alliance portfolio diversity, in line with Cohen and Levinthal (1989, 1990) we introduced the variable R&D INTENSITY (lagged one period) measured as a firm's R&D expenditures in year t-1 divided by the year t-1 sales. In the innovation literature, R&D expenditures are usually considered an input indicator of the efforts that firms make in establishing R&D that might eventually lead to an output (Hagedoorn and Cloodt, 2003); and a

[5] Note that firms are told to only indicate those partners with whom the firm "actively cooperated for technological innovation" so that outsourcing agreements without active R&D cooperation are not considered.

good indicator of a firm's innovative competences, particularly in high-tech industries (Duysters and Hagedoorn, 2001; Henderson and Cockburn, 1994). Therefore, consistent with our theoretical framework and the results of previous research, we consider this variable as a good measure of a firm's technological absorptive capacity and thus of its ability to handle external technological knowledge (Duysters and Hagedoorn, 2001; Hagedoorn and Cloodt, 2003; Laursen and Salter, 2006). Nevertheless, due to the correlation that may exist between a firm's R&D input (R&D intensity) with its R&D output through patents (Hausman et al., 1984; Hitt et al., 1997), and that there are studies that use performance feedback models to explain firms' R&D intensity levels (Bromiley and Washburn, 2011; Chen and Miller, 2007; Chen, 2008; Greve 2003a), we instrumented our variable R&D INTENSITY to avoid endogeneity concerns. In line with previous research (O'Brien and David, 2014), the procedure used to instrument this variable was to build a panel-data regression model in which the dependent variable was R&D INTENSITY lagged one period and the independent variable was its 2-lagged value controlled for firm sales and firm industry, as these two variables may influence firms' R&D intensity (see table 2).[6] The validity of our instrumentation was supported by running a Sargan test in a linear dynamic panel-data model (Sargan, 1958) as its results (Prob > chi2 = 0.2672) showed no sign of overidentification. Thus, thanks to this instrumentation, we were able to clearly separate what we consider the input (the R&D effort) from the output (patents).

We also analyzed whether there was any reverse causality between R&D intensity and our dependent variable by running a Granger causality test (1969). Our results showed that there is no sign of reverse causality. In addition, given that the diversity of technological partners can also affect innovation performance, we also ran this reverse causality test between our performance variables and our dependent variable. Overall, these results show that, although theoretically possible, reverse causality is not an issue in our empirical framework.

3.2.3. Control variables

To control for the firms' differences in resources and capabilities that may systematically influence alliance portfolio diversity, we introduced the following variables that have been commonly used in previous literature on innovation (Chapman et al., 2018; Cuervo-Cazurra et al., 2018). FOREIGN: a dummy variable that equals 1 if the firm has a capital structure with at least 50% of foreign capital. BUSINESS GROUP: a dummy variable that equals 1 if the firm belongs to a business group. INTERNATIONAL SALES: a dummy variable that takes the value of 1 if the firm sells products or services outside of the domestic country. To control for firm size effects, we introduced FIRM SALES, measured as log of the firm's total sales (in euros). Accounting for firm size is important as firms' resource endowment have been shown to affect decision makers' risk tolerance (Audia and Greve, 2006). To control for organizational inertia, we introduced FIRM AGE, measured as the number of years since the company's foundation (Coad et al., 2016). Because a firm's location within a science and technology park (STP) has been found to influence the intensity of the effect of spillovers on innovation and on R&D alliance activity (Martín-de Castro et al., 2011), we also controlled for this fact with the dummy variable STP LOCATION which equals 1 if the firm is located within a STP. Finally, to control for possible common shocks at the industrial level, we introduced 16 sectoral dummies for our medium to high technological industries according to the OECD classification, as well as year fixed effects.

To avoid further endogeneity issues, all the previous independent and control variables were lagged one year in our estimations since alliances require some time to be formed (Baum et al., 2005).

Table 2
Results from the instrumental variable estimation (panel data regression).

Correlation	1	2	VIF
1. R&D intensity (t-1)			
2. R&D intensity (t-2)	0.3158*		1.03
3. Firm sales (t-1)	−0.1069*	−0.0824*	1.18
* $p<0.05$			

VARIABLES	Dependent variable: R&D intensity (t-1)
R&D intensity (t-2)	0.143**
	(2.08)
Firm sales (t-1)	−0.015 ***
	(4.19)
Intercept	0.369***
	(4.22)
Industry dummies	*included*
N	18,727

4. Analyses and results

Poisson regression is normally used to model dependent variables with count data such as ours, which only take discrete non-negative integer values. However, when the data are over-dispersed it can generate a downwardly biased covariance matrix, leading to small, incorrectly estimated standard errors (Haynes et al., 2003). To adjust for over-dispersion, we used the negative binomial model, a generalization of the Poisson model in which the assumption of equal mean and variance is relaxed (Cameron and Trivedi, 1998; Hausman et al., 1984). In addition, we conducted a model comparison analysis in STATA (with the user-written *count* function) and the analysis of the residuals revealed that the negative binomial regression was the best fitting model (Tyler and Caner, 2016). More specifically, because compared to random effects and fixed effects specifications the Generalized Estimating Equation (GEE) offers inherent advantages in terms of efficiency —and when accounting for unobserved heterogeneity (Hardin and Hilbe, 2003; Katila and Ahuja, 2002; Liang and Zeger, 1986)—, we used a GEE negative binomial estimator (Fernández-Méndez et al., 2018; Krishnan and Kozhikode, 2015) with an independent correlation structure and heteroscedasticity consistent standard errors.

Table 3 presents the summary statistics and the correlation matrix. The correlations between the variables of the study are low and do not suggest that collinearity is a problem. Despite this, we also computed the variance inflation factors (VIFs) for all our key variables to identify possible collinearity issues and, as can be observed in table 3, all VIF values are well below the commonly accepted threshold of 10.

The results of GEE negative binomial analysis are shown in table 4 under six different specifications. Model 1 represents the baseline model with only the control variables. Model 2 adds the main effects of the independent variables. Model 3 adds the moderator variable. Model 4 includes the interaction effect of the moderator variable for firms with innovation performance below their aspiration levels. Model 5 adds the interaction but for firms performing above their aspiration levels. And model 6 is the fully specified model. The six models are statistically significant as shown by the Wald Chi-square test ($p<0.001$). In addition, the results are consistent across models, so we will rely on the full model 6 to discuss our interaction effects.

Our first hypothesis stated that increases in the distance of innovation performance below aspiration levels will lead to increases in alliance portfolio diversity. As it can be observed, our variable INNOVATION PERFORMANCE BELOW ASPIRATIONS is positive and highly significant across models, showing, as predicted by hypothesis 1, that increases in the distance of innovation performance below aspiration levels will lead to increases in alliance portfolio diversity (as mentioned, it was reverse-coded) with a $p<0.001$. In the same vein, our variable INNOVATION PERFORMANCE ABOVE ASPIRATIONS is positive and highly significant across models ($p<0.001$), supporting our

[6] We also instrumented our R&D intensity variable in t-1 using its 3–lagged value obtaining similar results.

Table 3
Summary statistics, correlation matrix and VIFs.

		Mean	S.d.	1	2	3	4	5	6	7	8	9	VIF
1	ALLIANCE PORTFOLIO DIVERSITY	1.24	2.47	1									
2	INNOVATION PERFORMANCE BELOW ASPIRATIONS	0.44	3.01	0.04*	1								1.01
3	INNOVATION PERFORMANCE ABOVE ASPIRATIONS	0.43	6.37	0.14*	−0.01	1							1.01
4	R&D INTENSITY	0.04	0.46	0.03*	0.00	0.00	1						1.02
5	FOREIGN	0.16	0.36	0.11*	0.02*	0.04*	−0.02*	1					1.29
6	FIRM AGE	35.10	18.04	0.09*	0.00	0.03*	−0.04*	0.13*	1				1.12
7	INTERNATIONAL SALES	0.81	0.38	0.10*	0.02*	0.02*	−0.02*	0.14*	0.13*	1			1.07
8	FIRM SALES (log)	16.01	1.88	0.29*	0.03*	0.08*	−0.09*	0.38*	0.30*	0.30*	1		1.81
9	BUSINESS GROUP	0.45	0.49	0.24*	0.02*	0.05*	−0.01*	0.44*	0.12*	0.15*	0.57*	1	1.66
10	STP LOCATION	0.02	0.16	0.10*	0.01*	0.01*	0.05*	−0.01*	−0.07*	0.02*	0.02*	0.04*	1.01

* $p<0.05$.

Table 4
GEE negative binomial regressions predicting alliance portfolio diversity.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
INNOVATION PERFORMANCE BELOW ASPIRATIONS			0.010 (5.89)***	0.018 (4.66)***	0.010 (5.93)***	0.017 (4.40)***
INNOVATION PERFORMANCE ABOVE ASPIRATIONS			0.014 (5.94)***	0.014 (5.89)***	0.015 (8.84)***	0.014 (8.50)***
R&D INTENSITY (instrumented)		6.665 (41.74)***	6.306 (39.49)***	6.534 (41.22)***	6.169 (37.20)***	6.385 (38.66)***
INNOVATION PERFORMANCE BELOW ASPIRATIONS X R&D INTENSITY				−0.622 (2.71)***		−0.553 (2.42)**
INNOVATION PERFORMANCE ABOVE ASPIRATIONS X R&D INTENSITY					0.223 (5.46)***	0.204 (4.77)***
FOREIGN	−0.083 (1.17)	−0.102 (1.38)	−0.095 (1.30)	−0.096 (1.31)	−0.089 (1.22)	−0.091 (1.24)
FIRM AGE	0.001 (0.43)	0.001 (0.77)	0.001 (0.91)	0.001 (0.95)	0.001 (0.84)	0.001 (0.89)
INTERNATIONAL SALES	0.305 (3.54)***	0.325 (3.51)***	0.329 (3.51)***	0.328 (3.49)***	0.324 (3.46)***	0.324 (3.45)***
FIRM SALES (log)	0.314 (15.19)***	0.465 (22.72)***	0.445 (22.37)***	0.442 (21.99)***	0.441 (22.31)***	0.439 (22.03)***
BUSINESS GROUP	0.607 (9.40)***	0.563 (8.33)***	0.555 (8.14)***	0.555 (8.13)***	0.55 (8.07)***	0.551 (8.07)***
STP LOCATION	0.623 (5.71)***	0.561 (5.35)***	0.563 (5.27)***	0.569 (5.28)***	0.564 (5.25)***	0.569 (5.26)***
Intercept	−5.576 (16.92)***	−8.121 (25.13)***	−7.822 (24.64)***	−7.784 (24.17)***	−7.759 (24.60)***	−7.731 (24.26)***
Industry effects	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Year effects	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Wald chi-square	627.2***	2449.3***	2363.3***	2665.3***	2500.4***	2782.8***
N	17,883	14,392	14,222	14,222	14,222	14,222

z-statistics in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

hypothesis 2 stating that increases in the distance of innovation performance above aspiration levels will lead to increases in alliance portfolio diversity. Consistent with our third hypothesis predicting that R&D intensity decreases the propensity to increase technological alliance portfolio diversity when performing below expectations, we find that the interaction term INNOVATION PERFORMANCE BELOW ASPIRATIONS*R&D INTENSITY is negative and highly significant in model 4 ($p<0.01$) and model 6 ($p<0.001$). Finally, consistent with our last hypothesis (hypothesis 4) stating that R&D intensity increases the propensity to increase technological alliance portfolio diversity when performing above expectations, we find that the interaction term INNOVATION PERFORMANCE ABOVE ASPIRATIONS*R&D INTENSITY is positive and highly significant in both models 5 and 6 ($p<0.001$). For a better understanding of these moderation effects, we display them for different values of firms' R&D intensity; that is, when the R&D INTENSITY variable takes a low value (10th percentile) an average value (50th percentile) and a high value (90th percentile) (see Fig. 2). As it can be clearly observed in Fig. 2, our results support our hypotheses.

Due to the difficulty of interpreting interaction effects in nonlinear models, we also computed the marginal effect of our moderator variable on the relationship between the dependent variable and our explanatory variables (see Fig. 3). This marginal effect (or true interaction effect) is computed as the cross partial derivative of the nonlinear regression equation (Ai and Norton, 2003; Wiersema and Bowen, 2009). In this graph, it is observed more clearly the negative marginal effect of R&D INTENSITY on technological alliance portfolio diversity for those firms performing below aspiration levels (PBA) and the positive marginal effect that R&D INTENSITY has on alliance portfolio diversity for those

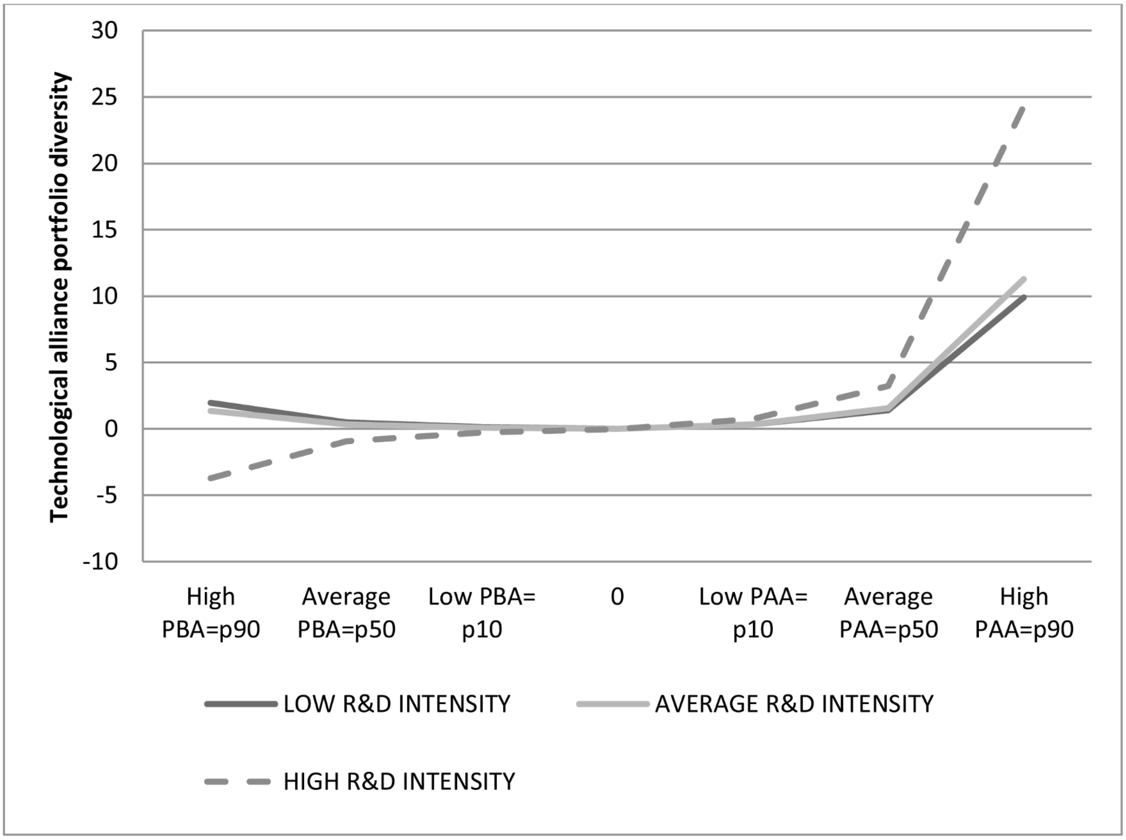

Fig. 2. Moderating effect of R&D intensity on technological alliance portfolio diversity for firms performing below innovative aspirations (PBA) and above aspirations (PAA).

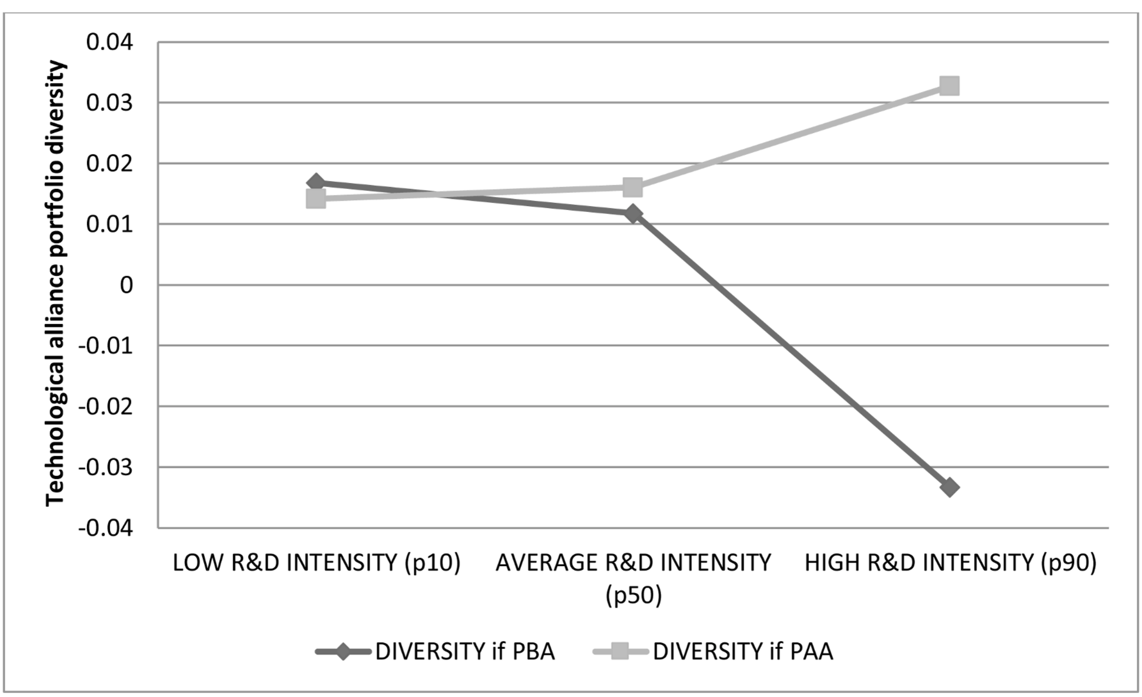

Fig. 3. Marginal effect of R&D intensity on the relationship between relative innovation performance and technological portfolio alliance diversity.

firms performing above aspiration levels (PAA).

Finally, in relation to the control variables, our results show that our variables INTERNATIONAL SALES and FIRM SALES are highly significant across models suggesting that large firms are more willing to increase alliance portfolio diversity. These results are in line with those of Audia and Greve (2006) who found that having an excess of resources (proxied by firm size) lead firms to make risky choices. It seems that large firms accumulate resources and capabilities, either because of their domestic or international experience, making them more willing to take the risks associated with increased alliance portfolio diversity. The results of the STP LOCATION and BUSINESS GROUP variables again appear to confirm the importance of resource availability in risky choices, as firms that can gain access to the resources of the business group, or those available in a specific location, have higher chances of expanding the size and diversity of their alliance portfolio.

4.1. Robustness checks

Despite the fact that patents are considered in the innovation literature as a valid indicator of innovation performance and technological competence in technology-intensive industries (Hagedoorn and Cloodt, 2003), and that the existing previous behavioral studies on performance feedback have also used patents as an indicator of firms' innovative performance, its use presents some limitations. Although patents can capture firms' innovativeness, they can be also the result of their appropriability strategy (Teece, 1986; Chesbrough, 2003) as there are other multiple strategic motives to patent besides protecting from imitation (improve reputational image, improve bargaining power with third parties, or block competition, among others); see Blind et al. (2006) for a review. Furthermore, there are patents that are not commercialized, or innovations that cannot be patented or are not worth patenting (Arora et al., 2008). It is for this reason that to account for the fact that patenting may not be as important for all firms we decided to run additional tests by removing from our sample those firms who never patented in the period under study (2008–2015). As a result of this filter, our dependent variable lost 14,666 observations, although maintaining a very similar distribution (see table 5). The results of these new estimations are shown in table 6. As it can be observed, despite removing those firms with no patenting activities, all our results hold and even with stronger effects (particularly for the interaction between INNOVATION PERFORMANCE BELOW ASPIRATIONS and R&D INTENSITY) with all models offering a very high value of the Wald Chi-square test ($p<0.001$). Therefore, we believe that, despite the shortcomings that the use of patents can have as an indicator of a firm's innovation performance, our results are not biased by firm differences in patent propensity.

Table 5
New distribution of our dependent variable when removing firms with no patenting activity.

ALLIANCE PORTFOLIO DIVERSITY	N	Percent
0	3642	52.1
1	828	11.84
2	597	8.54
3	496	7.09
4	313	4.48
5	259	3.7
6	236	3.38
7	144	2.06
8	107	1.53
9	77	1.1
10	83	1.19
11	40	0.57
12	31	0.44
13	31	0.44
14	30	0.43
15	20	0.29
16	13	0.19
17	15	0.21
18	11	0.16
19	4	0.06
20	1	0.01
21	5	0.07
22	4	0.06
24	2	0.03
26	1	0.01
27	1	0.01
Total	6991	100

In addition to this robustness check, we also ran our estimations with two alternative dependent variables based only on the organizational dimension of diversity, i.e. the types of technological partners with whom the firm cooperates (other firms of the same group, customers, suppliers, competitors, universities, commercial labs and research centers). The first model we tried used as the dependent variable just the count of the number of different types of partners with whom the firm was collaborating for technological innovation for each period. The second model included a more refined measure of this variable using survey data information on the number of external partners of the firm that were considered by the respondent firm as important sources of knowledge for each period. These two alternative dependent variables range from 0 to 7 and when running alternative models with each of them our results hold. Taken as a whole, this second set of results proves the robustness of our findings to alternative measures of diversity.[7]

5. Discussion and implications

Our behavioral model for how technology-intensive firms reconfigure their alliance portfolio diversity as a response to innovation performance feedback has been confirmed by our data. Aligned with behavioral theory, we find that as firms deviate (either above or below) from their performance aspiration levels, they decide to embrace changes in their alliance portfolio, confirming our hypotheses 1 and 2. These results complement previous research applying the insights of the behavioral theory of the firm to the field of R&D. The pioneering work of Greve (2003a) confirmed Cyert and March's (1963) insight that firms performing above or below their financial aspirations tend to increase R&D spending. More recently, Kavusan and Frankort (2019) found that firms deviating from their innovation performance aspiration level also increase the number of their R&D alliances. Our results add to the recent and very scarce literature on the impact of innovation performance feedback on R&D alliance portfolio decisions (Tyler and Caner, 2016; Lungeanu et al., 2016; Kavusan and Frankort, 2019) by showing that when deviating from their innovative aspiration levels both underperformers and overperformers tend to increase their alliance portfolio partner diversity (in terms of types of partners and regions of origin).

We also contribute to behavioral theory research by studying factors that may explain why firms respond to performance feedback heterogeneously (Greve and Gaba, 2017; Kavusan and Frankort, 2019; Kotiloglu et al., 2021; Shinkle, 2012). We highlight the role of R&D intensity in delineating the boundary conditions of our model. Previous research has highlighted how R&D intensity influences the outcomes of R&D collaboration (e.g. Berchicci et al., 2016; Xie et al., 2019). However, to the best of our knowledge, ours is the first research showing the moderating role of R&D intensity on the impact of innovative performance feedback on alliance formation. As expected in our model, our results show that firms' response to their innovation performance feedback is also dependent on their level of R&D intensity, but in a different direction depending on the performance discrepancy being positive or negative. Building on previous research on absorptive capacity, it is our point that R&D intensity captures the ability of the firm to identify and detect prospective partners as well as to manage those agreements based on its technological absorptive capacity and previous experience, regardless of other outcomes of these activities. As argued by Cohen and Levinthal (1989, 1990), Laursen and Salter (2006) and Bertrand and Mol (2013), among others, absorptive capacity is an additional outcome of R&D activities besides the specific inventions generated. Although innovation performance can also proxy absorptive capacity, by introducing patents and R&D intensity in the same equation (but with different time lags) we believe we can capture the two outcomes of R&D separately: inventions (which can be influenced by

[7] These results are available from the authors upon request.

Table 6
GEE negative binomial regressions predicting alliance portfolio diversity when removing firms with no patenting activity.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
INNOVATION PERFORMANCE BELOW ASPIRATIONS			0.006	0.015	0.006	0.014
			(4.96)***	(4.49)***	(5.04)***	(4.27)***
INNOVATION PERFORMANCE ABOVE ASPIRATIONS			0.008	0.007	0.008	0.008
			(4.23)***	(4.37)***	(6.75)***	(6.41)***
R&D INTENSITY (instrumented)		1.182	1.1	1.265	1.015	1.186
		(7.35)***	(6.87)***	(8.31)***	(6.23)***	(7.60)***
INNOVATION PERFORMANCE BELOW ASPIRATIONS X R&D INTENSITY				−0.644		−0.598
				(3.05)***		(2.82)***
INNOVATION PERFORMANCE ABOVE ASPIRATIONS X R&D INTENSITY					0.113	0.094
					(3.29)***	(2.58)***
FOREIGN	−0.029	−0.047	−0.043	−0.045	−0.033	−0.036
	(0.32)	(0.48)	(0.45)	(0.47)	(0.35)	(0.38)
FIRM AGE	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001
	(0.64)	(0.64)	(0.51)	(0.43)	(0.61)	(0.52)
INTERNATIONAL SALES	0.044	0.019	−0.003	0.001	−0.007	−0.002
	(0.32)	(0.12)	(0.02)	(0.01)	(0.04)	(0.01)
FIRM SALES (log)	0.247	0.294	0.279	0.272	0.278	0.272
	(8.02)***	(9.19)***	(8.89)***	(8.64)***	(8.88)***	(8.64)***
BUSINESS GROUP	0.655	0.617	0.604	0.603	0.599	0.598
	(7.00)***	(6.31)***	(6.16)***	(6.13)***	(6.10)***	(6.08)***
STP LOCATION	0.448	0.409	0.407	0.411	0.402	0.407
	(3.78)***	(3.29)***	(3.25)***	(3.29)***	(3.21)***	(3.25)***
Intercept	−4.171	−4.814	−4.574	−4.473	−4.548	−4.459
	(8.88)***	(9.74)***	(9.38)***	(9.13)***	(9.37)***	(9.13)***
Industry effects	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Year effects	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Wald chi-square	5068.5***	4629.9***	4657.7***	4722.5***	4667.2***	4726.5***
N	5907	4875	4817	4817	4817	4817

z-statistics in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

external factors, and even by luck, and are easy to observe); and technological absorptive capacity (activated by R&D efforts irrespective of the inventions generated).

The results of our hypothesis 3, related to the scenario of those firms performing below innovation aspirations but with absorptive capacity, due to their R&D intensity, are especially interesting. Although we expect underperforming firms to engage in problemistic search in an attempt to catch up, the confirmed negative moderating effect of R&D intensity shows that those firms with high levels of R&D intensity are reluctant to increase partner diversity. These results may be indicative of the fact that being aware of their low degree of attractiveness for new partners due their poor recent innovative performance, and thus, low bargaining power to negotiate new alliances in favorable terms (Ahuja, 2000b; Kim and Rhee, 2017; Blind et al., 2006), these firms prefer to reconfigure their existing alliance portfolio by downscoping it, keeping only the current successful alliances, maintaining or even reducing their partner diversity, as shown in Fig. 3.

In the case of hypothesis 4, which applies to firms performing above expectations, increases in partner diversity are observed in all cases, but R&D intensity amplifies the propensity to increase alliance portfolio diversity. Indeed, performing above aspirations in innovation should attract more partners and imply some absorptive capacity (Levinthal and March 1981). In fact, although all overperforming firms are somewhat expected to be opened to increase partner diversity, firms with higher levels of R&D intensity are expected to be the ones better prepared to make a sound assessment of the risks and returns of increasing alliance portfolio diversity and, thus, to direct their slack search behavior towards widening it.

Overall, our results for hypotheses 3 and 4 suggest that firms with high technological absorptive capacity maintain a completely different attitude towards alliance portfolio diversity. While we found that firms deviating above or below their innovative aspirations tend to widen their alliance portfolio diversity, in the subgroup of firms with high R&D intensity, only overperforming ones opt for expanding the diversity of their partners. We interpret this different behavior based on the firms' ability to attract new partners in favorable terms depending on their recent innovative performance. Indeed, as shown by previous research, technologically successful firms are in the best position to arrange a negotiated environment with the best partners available (Blind et al., 2006) and this could explain why, although both successful and unsuccessful firms may increase their R&D efforts, most great inventions come from successful firms (Cyert and March,1963). In line with this research, our results may be indicative of the fact that those firms more capable to manage technological alliances, due to their previous R&D efforts, know that increasing alliance portfolio diversity in a situation of underperformance would not deliver the expected results; and make them reluctant to form new alliances under these circumstances. While, on the contrary, those underperformers less prepared to make the most of these more diverse alliances would take the risks anyway.

Our study also contributes to the shed light on the debate on the link between performance and alliance portfolio diversity. Previous research has mainly focused on the performance consequences of alliance portfolio diversity (Lee et al., 2017), paying less attention to the question of how performance feedback influences alliance portfolio diversity, and more specifically partner diversity. Although performance feedback models have been applied to address a variety of research questions, to the best of our knowledge, little is known about its influence on technological alliance partner diversity. Performance feedback models have been applied to analyze different types of organizational change decisions such as levels of R&D investment (Chen, 2008; Greve, 2003a, 2003b), formation of R&D alliances (Tyler and Caner, 2016), and change in technology-sourcing vehicles (Lungeanu et al., 2016). As far as we know, apart from a recent paper of Kavusan and Frankort (2019), there exists scarce evidence in previous alliance management literature on the relationship between innovation performance feedback and technological alliance portfolio diversity. Our paper contributes to fill this gap by analyzing how R&D intensity moderates the aforementioned relationship.

Although not all organizational changes imply high levels of risks (Kacperczyk et al., 2015), the change analyzed in this paper —entering a partnership with a new firm to actively cooperate for technological innovation— always entails risks (Oxley 1997; Hagedoorn, 2002), especially if the partner is from a different type or comes from a new geographical area (Baum et al., 2005). For this reason, our paper can shed light on the relationship between performance aspirations and risky change. Consistent with conventional models of the behavioral theory of the firm (Cyert and March 1963; Greve 2003a), we found that both overperforming and underperforming firms are willing to undertake a risky change (in our case, widen the scope of their alliance portfolio). Nevertheless, our results introduce some nuances to the straightforward application of the behavioral theory of the firm. When the firms' degree of attractiveness for external partners is high due to their innovative overperformance, only the group of firms better prepared to manage technological alliances take advantage of the opportunity. On the contrary, when their attractiveness is low, they refuse to cooperate. Hence, the decision to undertake risky changes is not necessarily related to being below or above the aspiration level, but to being aware of what the expected outcomes (positive and negative) of the decision are and proceeding accordingly, as shown by firms with high levels of R&D intensity.

In conclusion, our results show that the same action (i.e. widening the R&D alliance portfolio diversity) can be either a somewhat risky measure to correct an underperforming situation (problemistic search) or just an opportunity to reinforce the firm's technological edge (slack search). In this way, our results complement those of Xu et al. (2019) showing how firms in the process of problemistic search are even willing to undertake unethical or illegal actions, whereas firms immersed in slack search undertake actions that reinforce their long-term competitiveness and growth opportunities. Thus, the slack search process associated with overperformance can be considered an opportunity for a firm to consolidate its leadership position by making the most of the new partnering possibilities. This is an important implication of our results: technologically overperforming firms in technology-intensive industries can enter a virtuous cycle if they capitalize on their success by establishing alliances for developing the technologies of the future. To secure their competitive position, firms in these industries need to secure access to new technologies and developments. However, not all firms are equally prepared to do it depending on their R&D intensity, nor have the same opportunities, depending on their attractiveness for new partners. Therefore, an emerging policy implication of our study is that, when deciding for public funding allocation, policymakers might use not only a firm's innovation performance but also its R&D intensity as a proxy of technological alliance management capabilities to identify the most promising R&D collaborations. Irrespective of their patenting outcomes, their absorptive capacity put R&D intensive firms in a good position to extract more value from alliances with more diverse partners. Indeed, this is especially relevant within the Spanish innovation context characterized by a high proportion of small and medium firms that have traditionally tended to rely heavily on public research founding, especially during the economic crisis of 2008 (Vega-Jurado et al., 2009; Cruz-Castro et al., 2018). Although policymakers in Spain have traditionally focused on strengthening the public research system encouraging cooperation with public research organizations (Vega-Jurado et al., 2009), it should be noted that collaboration with other types of non-scientific partners has been found to have a higher impact on firm's innovativeness (Gómez et al., 2020). Taking this into account, our study suggests that policymakers should concentrate their efforts not only on strengthening the technological capabilities of firms through public R&D founding, but at the same time on promoting cooperation with other diverse private partners helping firms to reach the benefits of this external distant knowledge that may help them to overcome the path dependency resulting from their resource endowments.

5.1. Limitations and future research directions

We identified different opportunities to extend our research and address some of its limitations. First, when a firm's performance deviates from its aspirational levels, the firm can react not only by increasing or decreasing its degree of partner diversity but also by opting for other forms of portfolio reconfigurations such as to reinforce current alliances, terminate some of them, or even form alliances with new partners with the same background as current partners. In this sense, while we acknowledge that there may be alliances that are riskier compared to others, we do not distinguish between the different risks that each type of partner or region of origin may generate for the firm. While this can be considered as a limitation of our study, due to the nature of our data, it also constitutes an opportunity for further research. Second, there is evidence that shows that firms' cultural and institutional contexts may influence their strategic responses to performance feedback (Lewellyn and Bao, 2015; O'Brien and David, 2014). For this reason, one limitation of our study is that our empirical sample was limited to Spanish firms, which means that cross-country studies would be useful to verify the generalizability of our results in other contexts. Third, we are not controlling for the slack financial resources available to these firms; which is a variable that has been traditionally considered by behavioral studies to impact firms' organizational responses (Greve, 2003a; Kotiloglu et al., 2021; Zhang and Greve, 2019). As explained when developing our hypotheses, due to the specificities of technological sectors, our study assumes that those firms with innovative outcomes above aspirations will have the resources to embrace in what we refer to slack (or explorative) search. This is so because despite maybe not having them internally, they are expected to be able to easily borrow them externally due to their promising innovative results. However, we acknowledge that the abundance of financial resources may impact firms' organizational responses. Unfortunately, our survey data does not allow us to accurately control for the availability of these slack resources. This prevents us from testing the existence of ambiguity in performance feedback due to conflicts between financial and non-financial performance feedback (Joseph and Gaba, 2015). We acknowledge that this ambiguity may also lead to different reactions in a firm's alliance decisions and we encourage further research to address this issue. Indeed, previous behavioral research found that depending on whether firms have consistent or inconsistent performance levels, their level of attention to historical versus social reference points can shift when determining their performance aspirations levels (Audia and Greve, Hu et al., 2017; Kacperczyk et al., 2015; Washburn and Bromiley, 2012) or even change their reference groups (Moliterno et al., 2014).Therefore, future studies could apply these insights when computing innovation performance aspiration levels, as well as to consider how an organization's structure, or even the characteristics of the decision makers, may affect the decision making processes and thus lead to distinct responses to performance feedback as shown by recent research (Joseph and Gaba, 2020; Rhee et al., 2019; Zhang and Greve, 2019). In this way, for example, our paper has not considered either theoretically or empirically the role that a firm's network can play in the reconfiguration of its alliance portfolio. Structural antecedents can also influence firms' motivations and opportunities to change (Kim and Rhee, 2017; Shijaku et al., 2020). Due to our focus on new contexts and to some limitations in our data these factors have not been considered, but they should be tackled in future works.

Credit author statement

All persons who meet authorship criteria are listed as authors, and the two authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, and revision of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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