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REVIEW ESSAY

What more can we learn from R&D alliances? A review and research agenda

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Abstract R&D cooperation has become a core aspect of the innovation strategy of R&D-performing organisations over the last three decades. Globalization has increased the imperative to organise these cross-border, inter-firm agreements efficiently, and this has led to a cross-fertilisation of ideas from a variety of fields, including international business, management, geography and, more recently, psychology. The aim of this paper is to review and synthesise this literature to identify new directions for research. The breadth of the academic discussion has evolved towards a general consensus on governance choice decisions, motives for collaboration, partner selection decisions and performance implications. Despite having achieved some degree of clarity on these issues, the growing complexity and international nature of these alliances requires a multidisciplinary approach, both in relation to the theories to apply, as well as in the type of data needed.
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Introduction

Greater cross-border competition means that nowadays there is no firm capable of staying competitive by relying on entirely on its internal resources and capabilities (Contractor et al., 2010; Das and Teng, 2000; Suarez and García-Canal, 2003). While this need of accessing external resources is common to firms in all sectors, the need to collaborate with external agents—i.e. suppliers, customers, competitors, universities or institutions—is even more evident in technological sectors (Kedia and Mooty, 2013; Quintana García and Benavides Velasco, 2007). More must be done with limited R&D budgets, as products and services are increasingly multi-technology, and this growing breadth of competences raises the costs and the associated risks (Leiponen and Helfat, 2010). Firms are forced to innovate at a faster rate so as to maintain their competitiveness in the market and, as a result, they see technological or R&D alliances not as an option, but as a strategic need (Cassiman and Veugelers, 2006). Previous literature has shown that accessing external technological knowledge through R&D alliances may help firms to reduce time-to-market, develop innovations that otherwise could not be done internally,

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improve the quality and efficiency of the innovations developed, as well as facilitate the access to new markets (Narula, 2001). This reflects a broader phenomenon, as cooperation at all aspects of the value chain is an essential part of economic activity, as seen by the growth in global value chains (Hernández and Pedersen, 2017) and innovation networks. In addition, universities, research institutes (not to mention governments, and supra-national organisations) all seek to create greater efficiencies. R&D cooperation is a complex activity, as given its strategic role and usually tacit and firm-specific nature, is an activity that, if poorly planned and managed, has long-term consequences that can threaten firm's survival.

Despite the benefits, R&D alliances are risky (Monteiro et al., 2017). They require partners to transfer and communicate technological knowledge that is usually difficult to codify and protect, thus generating important hazards for the partners (Cantwell and Santangelo, 1999; Oxley, 1997). This means that firms have to try to maximise coordination and communication so as to fully benefit from the partner's external knowledge, while at the same time protecting their knowledge from undesired technological leakages (Grimpe and Kaiser, 2010; Martínez-Noya et al., 2013). In other words, firms face an inter-organisational learning dilemma (Larsson et al., 1998). This tension between knowledge sharing and knowledge protection may lead to other paradoxes when selecting alliance partners, such as a higher preference for familiar and nearby partners especially for more radical projects (Li et al., 2008) which may bias partner selection decisions and lead to the paradox of embeddedness (Uzzi, 1996, 1997).

For this reason, the aim of this paper is to review the literature on R&D alliances to summarise what we know and identify the main challenges for future research. We believe that, despite the vast literature analysing R&D cooperation, there are many dimensions of R&D alliances that require a better understanding. Given their strategic nature, R&D alliances provide important insights into other types of alliances as they require greater diligence and planning. Therefore, the literature on R&D alliances has consistently foreshadowed (and even predicted) our understanding of cooperation in other value-adding activities. In general, although analysed from different disciplines—such as management, international business, and innovation—, the themes of this research have been consistent around the same questions, although the degree of analysis and precision has become increasingly more sophisticated. Given the multidisciplinary nature of the research on R&D alliances, this paper tries to identify future research opportunities from the current streams of enquiry in R&D alliances that can still be framed within these questions:

- *Why* do firms engage in R&D alliances? What are the *motivations* for undertaking these partnerships?
- *What* kinds of activities are undertaken? How and why has the *scope* of activities within R&D alliances changed?
- With *whom* and *where* do firms partner? How do firms select *partners*? Does *location* matter?
- *How* do firms undertake alliances? How does *contract design* influence alliance development and performance?
- *How* do R&D alliances impact innovation and/or financial *performance*? What factors moderate this alliance-performance relationship?

Our impression from our literature review is that the most interesting research opportunities emerge from the interlinkages between these questions, and require us to take a multidisciplinary approach that encompasses both the management and international business (IB) literatures. These questions are obviously hard to clearly delineate because in designing an alliance, they are interdependent. For instance, it is important to get a better understanding on how different motivations to form these technological agreements, and how discrete governance mechanisms (such as equity versus non-equity modes), or partner selection, may affect alliance outcomes (Diestre and Rajagopalan, 2012). Alliances also involve location decisions, which shape governance and partner selection decisions as well (Narula and Santangelo, 2012). Therefore, because firms increasingly utilise a global R&D portfolio (as also illustrated by the growing interest in open innovation), understanding how to ''orquestrate'' the effective governance of these agreements is crucial (Bogers et al., 2017). Conceptually, they require a wide-ranging set of concepts from sociology, game theory, industrial organisation, economic geography and international business, to name a few. More recently attention has been drawn to contract design (Contractor and Reuer, 2014) or behavioural theories as a means to analyse how more microfoundational aspects influence R&D alliance decisions (Das and Kumar, 2011; Martínez-Noya and García-Canal, 2015). We believe that this will allow a better understanding of how managers' perceptions or cognitive frameworks shape their alliance decisions in terms of their formation and development (Weber and Mayer, 2011).

The rest of the paper is structured as follows. First, we explain what we understand by R&D alliances and review their different typologies. Secondly, we focus on reviewing the literature according to the different key five questions that have been addressed on this theme (why, what, with whom, how and performance effects), to identify future research opportunities. Finally, we present the main conclusions that can be drawn from the study and highlight the main research opportunities that we identified.

The nature and typologies of R&D alliances

It is important to begin with a definition of what we understand to be R&D alliances. For our purposes, R&D alliances are innovation-based relationships formed by two or more partners who pool their resources and coordinate their activities to reach a common goal. These are relationships in which R&D activities constitute a significant part of the collaborative effort, and represent a particular subset of cooperative agreements (Hagedoorn, 2002; Oxley, 1997). They are also referred to as cooperative R&D, technological alliances, strategic technology partnering, or technological cooperative agreements (Narula and Martinez-Noya, 2015). Indeed, the lack of uniformity in their definition across the literature reflects the multidisciplinarity of the subject.

R&D alliances present many managerial challenges in their effective design and management. This is so because R&D alliances tend to require the exchange of tacit and firm-specific knowledge—knowledge that includes hard-to-communicate skills or know-how—that is difficult to codify and is better transferred through close interaction (Cantwell and Santangelo, 1999). When partners cannot clearly define property rights over knowledge, it becomes difficult for them to establish knowledge transfer barriers (Narula, 2001). In other words, the intensity of communication required among partners, generates important appropriability hazards (Kogut, 1988; Oxley, 1997). Appropriability hazards imply the risk of inadequate uses or modifications of the knowledge transferred that may leave the transferor worse off. Such a risk occurs either when: (1) the recipient partner takes advantage of that acquired knowledge to become a future competitor (Alcácer and Oxley, 2014); or (2) the knowledge gained by the recipient partner may benefit competitors with whom they may also be engaged with (Martínez-Noya and García-Canal, 2015). Partners face a critical dilemma: how do they maintain the necessary degree of collaboration and knowledge exchange to achieve the alliance objectives, while avoiding the unintended leakage of valuable technology (Grimpe and Kaiser, 2010; Mudambi and Tallman, 2010; Oxley and Sampson, 2004; Zhang and Baden-Fuller, 2010)? As we explain in the following sections, firms try to protect their knowledge through the design of complex and lengthy contracts, or by choosing familiar and trusted partners, which may diminish innovation performance.

These collaborative agreements for innovation can be horizontal (e.g. among rivals), vertical (e.g. with suppliers or clients) or institutional (with universities and research institutes) (Belderbos et al., 2004). Horizontal alliances are those formed among firms engaged in more or less the same kinds and types of value adding activities. They provide opportunities for economies of scale and scope, but are also prone to conflict and leakage of intellectual property. Vertical R&D collaborations are those between firms operating in related industries along the same value chain. They are especially important within global production networks and global value chains, and are especially common for development (as opposed to research). Overall, compared to vertical agreements, horizontal alliances tend to reflect a more complex strategic intent, and require closer collaboration (Narula and Hagedoorn, 1999; Narula, 2001). Besides this categorisation, previous research classifies R&D alliances into two groups: equity-based (joint ventures) and non-equity-based alliances (Das and Teng, 2000; Gulati, 1995; Hagedoorn, 2002). The increase of non-equity modes of governance offers higher flexibility compared to equity forms (Narula and Martinez-Noya, 2015; van Kranenburg et al., 2014). Nevertheless, R&D alliances can take many structural or organisational forms. Fig. 1 lists the most common types. In general, licensing agreements do not usually involve active collaboration, and knowledge flows tend to be one-way.[1] Licensing agreements are therefore passive conduits for knowledge flows, and are not normally qualified as alliances by themselves. Cross-licensing, mutual second sourcing or two-way licensing agreements do involve bilateral technology flows, thus requiring more extensive agreements, but in general terms they imply a low degree of collaboration. Indeed, these governance modes are—by definition—adopted where knowledge has been codified. Despite this, it should be noted that these agreements may be a precursor for more complex and intense collaboration, and may also be used with more intense collaboration, which means that these agreements may also have a strategic intent. Contractor and Reuer (2014) relate a typology of different R&D alliance types with the need of developing complex and lengthy contracts (see Fig. 2). Overall, the general argument is that increasing commitment, investment, and interdependence among partners is correlated with more complex and lengthy contracts due to greater knowledge concerns.

Nevertheless, it is important to note that the rank ordering in Figs. 1 and 2 is only illustrative because, as argued by Contractor et al. (2011: 68): ''... structure is not an end in itself. When it comes to creating and appropriating value or new technology in an alliance, learning from one's partner, improving the efficiency with which knowledge is transferred, coordinating with one's ally, or moderating their opportunism, it is the process and intensity of interactions between the personnel of the two companies—more than the legal or contractual form—that matter.'' Even the 'simplest' vertical alliance to supply a codified component can involve interactions between partners that go beyond just coordination to include key issues like the joint development of future technologies or the co-design of new products. Alliances evolve over time so trustworthiness among partners can result in the joint design and development of core components for next generation of technologies (Dyer and Chu, 2003), although this may also mean higher appropriability concerns.

Why do firms undertake R&D alliances? From cost to value-enhancing considerations

Globalisation of dynamic markets and the growing complexity and multidisciplinary nature of the innovation processes means that R&D cooperation is no longer seen as a sign of weakness. Indeed, to undertake all R&D activities internally within the firm is the exception. R&D alliances offer many different advantages, such as accessing complementary resources to develop new or improved products or processes, explore new markets, achieve lower costs, mitigate risks, or reduce time-to-market (Hagedoorn et al., 2000; Narula, 2001; Sakakibara, 2002).

Broadly speaking, the growth of R&D alliances has either been explained through the lens of transaction cost theory taking a economisation perspective (Pisano and Teece, 1989; Williamson, 1975), or by taking a more strategic perspective, through the use of a number of other different theoretical approaches, such as: the resource-based theory of the firm (Barney, 1991; Das and Teng, 2000; Wernerfelt, 1984),

[1] With the exception of maybe some sporadic flows due to legal clauses that require the licensee to feedback to the licensor for technical help, or for the adaptation of the technology to international markets.

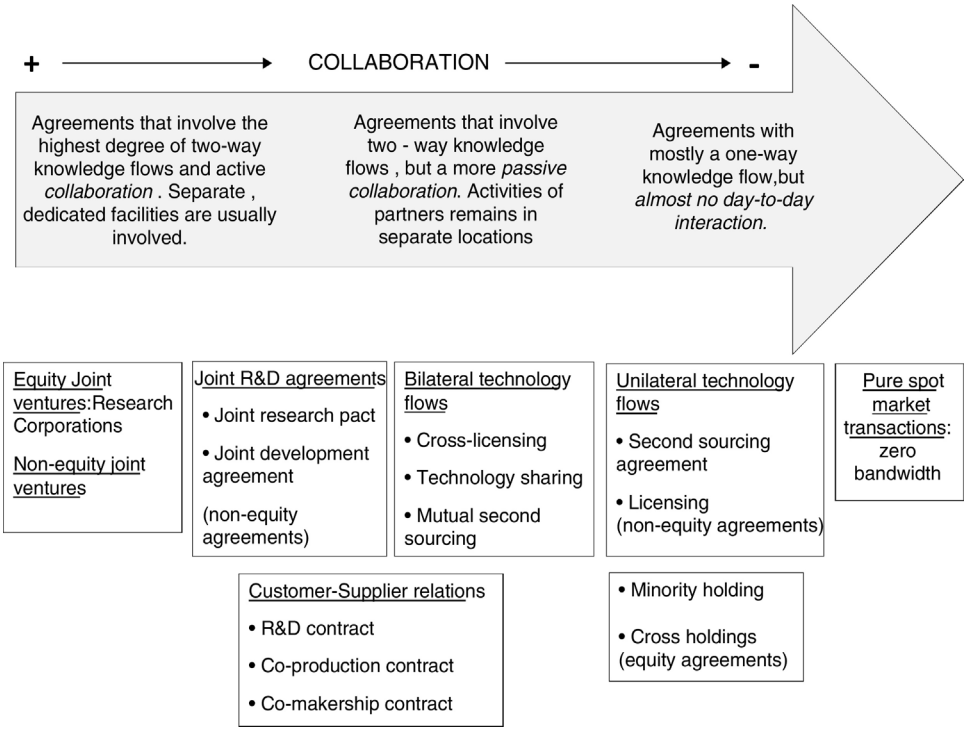

Figure 1 Organisational modes of R&D alliances and extent of inter-firm collaboration.

Source: Narula and Martinez-Noya (2015).

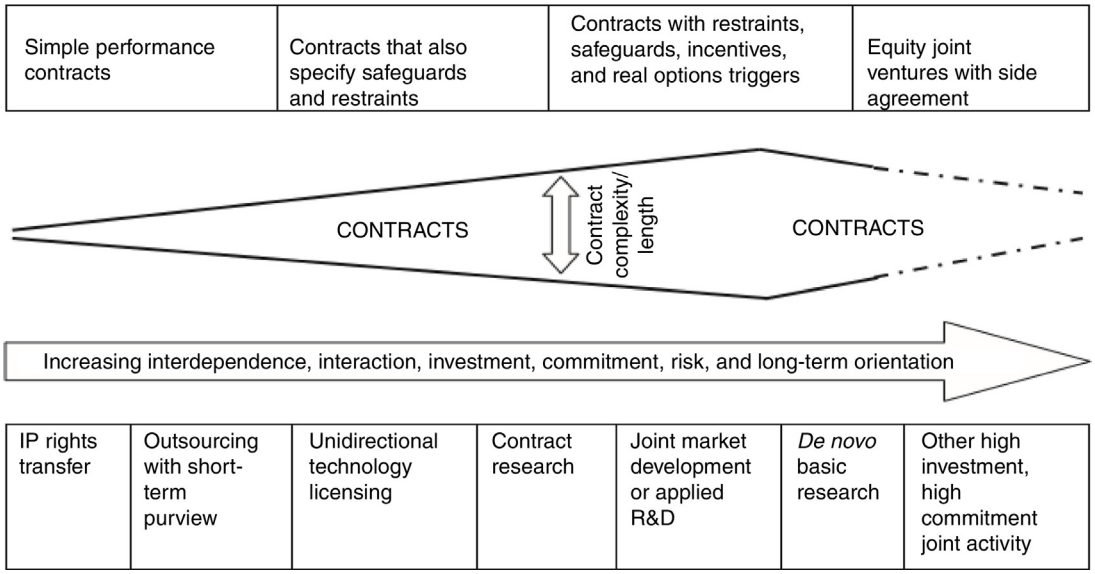

Figure 2 Complexity and length of contracts for different R&D alliance types.

Source: Contractor and Reuer (2014).

knowledge-based view and organisational learning (Kogut and Zander, 1993), social network theory (Gulati, 1995; Powell and Grodal, 2005), or even the dynamic capabilities approach (Teece et al., 1997; Zollo and Winter, 2002). In general terms, the key underlying difference between the economisation perspective and the more strategic ones is a fundamentally different view of the way firms make their decisions. Transaction cost theory assumes that firms' make versus buy decisions are driven by their willingness to reduce both production and transaction costs while protecting from opportunism (Hennart, 1988; Williamson, 1975). However, the transaction costs logic does not capture many of the strategic advantages that alliances can offer, such as market growth or inter-firm learning through alliances; motivations that during recent decades have become more important for firms to form R&D alliances (Narula and Dunning, 1998).

More recent R&D alliance literature has tended to emphasise that alliances are not only the result of a cost minimisation strategy, but also the result of value-enhancing considerations, such as market growth or inter-firm learning through alliances.

In this sense, strategic management theories, such as the resource-based view, highlight the fact that firms are boundedly rational and undertake decisions based on the need to enhance their technological and organisational capabilities (Das and Teng, 2000). From this perspective, firms form R&D alliances to create value by for example: acquiring complementary resources, leveraging existing resources, developing new (or improved) products and innovation capabilities or entering new markets (Sakakibara, 2002). These strategic drivers seemed especially relevant with the emergence of new technological sectors (such as biotechnology) and the growing technological convergence between industries (such as computers and automobiles, or new materials). The cross-fertilisation of technological areas implied that to stay competitive firms need to have a broader range of competencies (Granstrand et al., 1997), which encouraged the use of a portfolio of R&D alliances as a way to quickly access complementary resources and capabilities (Leiblein and Miller, 2003; Mol, 2005; Nicholls-Nixon and Woo, 2003; Quinn, 2000). R&D alliances offer the possibility to learn from the competencies of the partner because alliances are not only a means for taking advantage of external capabilities, but also a means for the transfer of such capabilities, as firms can internalise the know-how and skills that are the basis of their partners' capabilities (Hamel, 1991; Hong and Snell, 2013; Howard et al., 2016). However, such R&D alliances can accentuate the interorganisational learning dilemma that firms face as they can generate important managerial challenges for actors wishing to maximise learning while avoiding opportunism (Khanna et al., 1998).

Nowadays, both transaction cost minimising and value-enhancing reasons are regarded as complementary to each other, and indeed many studies combine both approaches (Lai and Chang, 2010) because very few agreements are distinctly driven by one motivation or the other.[2] Table 1 summarises the main incentives to form R&D alliances based on transaction costs and strategic management theoretical approaches (Hagedoorn et al., 2000).

In relation to this, evidence suggests that different types of R&D partners offer different advantages, which means that different alliance motivations will influence the type of partner to be chosen (Belderbos et al., 2004). However, the interlinkages that exist between the R&D alliance motivations and the type of partners have been less studied (Miotti and Sachwald, 2003) and offer promising research opportunities. For example, on the one hand, it has been long recognised the advantages that collaborating with customers can have so as to reduce the risks associated to the introduction of new products by reducing demand uncertainty (von Hippel, 2005). On the other hand, due to the specialisation advantages that an external supplier may offer, as a result of the aggregation of demands of related clients, cost-reduction is very frequently the motivation behind cooperation with suppliers (Chung and Kim, 2003). While, institutional cooperation (with universities and research centres) has been found to be useful for basic research, i.e. when the main objective of R&D cooperation is accessing new scientific knowledge required for breakthrough innovations (Tether, 2002).

Therefore, it would be very interesting to further investigate how firms may deal with motives or innovation objectives[3] that may present conflicting interests (Leiponen and Helfat, 2010), or how factors such as the firm size, sector or origin may influence firms' motivations to form R&D alliances and the type of partner to be chosen. Similarly, we still have only a limited understanding of the pattern of R&D alliances between firms from developed countries and firms in emerging ones. Some case studies have suggested that R&D alliances with developed multinationals were instrumental in the emergence of firms like China's Haier or India's Tata (Duysters et al., 2009). However, the factors driving Western firms to form R&D alliances with firms in emerging markets have not received too much attention (Jacob et al., 2013). In this sense, given that international R&D alliances may have exploitation or exploration orientations, it would be also interesting to analyse from a dynamic or evolutionary perspective, how firms from emerging economies, such as China, may have used R&D alliances with Western firms as a useful mechanism to catch-up with developed economies.

Finally, we argue that the future of this research field requires integrating insights from different disciplines, especially from psychological or behavioural theories, to more traditional managerial perspectives. For example, a good example is the recent work by Tyler and Caner (2016) that apply behavioural theory and find that increases in the distance of high technology firms' new product introduction performance below aspirations serve as a motivation for increases in R&D alliances, and slack intensifies this relationship. Thus, we call for further studies on how managers' expectations or aspirations may influence firms' R&D alliance formation decisions.

What is the scope of R&D alliance activity? Towards increased fragmentation and complexity

Firms have expanded the scope of their alliance activity, partnering with a variety of different actors including customers, suppliers, universities and competitors (Ashok et al., 2016; Nieto and Santamaría, 2007; Un et al., 2010). This reflects changes in their sourcing strategies as a variety of activities along the value chain are externalised (Hätonen and Eriksson, 2009; Kotabe and Mudambi, 2009), and this

[2] See Madhok (1997) or Argyres and Zenger (2012) for an in-depth analysis of this debate.

[3] One of the most used surveys in innovation studies is the European CIS survey (Community Innovation Survey) sponsored by the statistical agency of the European Union, lists the following innovation objectives: Replace outdated products; Improve product quality; Expand product assortment; Enter new markets or increase market share; Increase flexibility of production; Reduce labour costs; Reduce use of materials; Reduce use of energy; Fulfil government regulation or standards requirement; Mitigate environmental damage.

Table 1 Main motivations to form R&D alliances based on transaction costs and strategic management approaches.

Motivation to form a R&D alliance	
Transaction costs perspective	Strategic management perspectives
• Minimise cost of transactions involving intangible assets (technical knowledge) • Circumvent incomplete contracts • Avoid opportunistic market behaviour • Avoid high costs of internalising the activity	• Share R&D costs • Pool risks • Economies of scale and scope • Co-opt competition • Improve competitive position • Coordinate value chains with coalition partners • Increase efficiency, synergy, power through network • Access complementary resources to exploit own resources • Use collaboration as learning vehicle to accumulate and deploy new skills and capabilities • Learn from partners, transfer technology • Create new investment options

Source: Adapted from Hagedoorn et al. (2000).

includes areas that were traditionally vertically integrated, such as those related to the innovation process (Howells et al., 2008; Manning et al., 2008; Santamaría et al., 2010; Quinn, 2000). Furthermore, firms are increasingly externalising these R&D activities using an extensive portfolio of international alliances, not only in developed countries but also in developing ones (Doh, 2005; Jensen, 2009; Kedia and Mukherjee, 2009; Kotabe and Mudambi, 2009; Levy, 2005; Mol et al., 2004, 2005; Martínez-Noya and García-Canal, 2010; Martínez-Noya et al., 2012; Nieto and Rodríguez, 2011; Quintás et al., 2008). Indeed, its increased internationalisation is now due not only to demand factors (which tend to be associated with adaptive R&D in response to specific market needs), but also to supply-side ones (Narula and Zanfei, 2005). As a consequence, the R&D function is being disintegrated into different technologically separable R&D services that can be performed in different locations either by the firm or by an external partner (Lewin and Peeters, 2006; Lewin et al., 2009; Manning et al., 2008; Maskell et al., 2007), and therefore firms need to search for the optimal governance and geographical location of each of the activities or R&D services within their value chain.

One of the limitations of many studies has been that they usually consider the R&D function as a whole without distinguishing between types of R&D services or activities within the innovation process. However, the multidisciplinary and complex nature of the firms' innovation process has induced firms to disintegrate their R&D process into several different and technologically separable R&D aspects (Fosfuri and Roca, 2002; Pavitt, 1999). In relation to these decisions about how and which activities to externalise, it is often argued that companies should keep core activities in-house, and externalise non-core ones. However, as argued by Linares-Navarro et al. (2014) it is still not clear what ''core'' activities are and how they can be differentiated from ''non-core'' activities, and whether this division is dichotomous. Getting a better insight on this is important because, due to the changing competitive landscape, firms are redefining their core activities, and some activities previously viewed as core activities are being detached from the core and started to be also externalised (Linares-Navarro et al., 2014).

Although there is no doubt that the type of activity being externalised will have an impact on alliance decisions such as governance, preferred location or type of partner, there are very few studies that have studied this fragmentation of the innovation process (Howells et al., 2008; Martínez-Noya et al., 2012). For this reason, research opportunities arise in the study of how what is being externalised influences alliance location decisions, the type of partner preferred, or the governance of the alliance. However, understanding carefully what can be externalised (and by extension, what should not) is complex. Externalising R&D imposes many difficulties, which are expected to be even higher when allying with partners in economies offering low protection of intellectual property rights (Zhao, 2006). This is so because the firms' capability of effectively protecting the knowledge transferred will be lower, and thus firms may need to make a higher use of secrecy as an informal way to protect its knowledge (Monteiro et al., 2017).

Indeed, recent research has found that the increased level of sophistication of the externalised activities offers greater learning opportunities for the partners (Li et al., 2010). Thus positive effects of increased interaction and collaboration may come at the cost of higher appropriability hazards, which may lead partners to adopt safeguards by deciding to limit their interaction in order to block undesired knowledge leakages (Kale et al., 2000; Lado et al., 2008). In this line, Gooris and Peeters (2016) found that when offshoring to locations offering low protection of IPR, firms tend to fragment the operations entrusted to foreign units, assigning services with a less strategic content as a way to reduce misappropriation problems. Due to the important implications that the level of sophistication of the externalised R&D activities is expected to have on all alliance decisions, such as partner selection, or governance, we call for future research to make a more fine-grained distinction between 'core' and 'non-core', or peripheral, activities to better identify which are indeed the types of R&D services

object of these partnerships. Indeed, among the few studies that have analysed these practices at the transaction level it has been found that the attributes of what is being externalised has a significant impact on location decision. Doh et al. (2009) found that services of a routine and repetitive nature are more likely to be offshored to countries with lower wages. While Martínez-Noya et al. (2012) found that R&D services requiring more tacit knowledge are likely to be externalised for knowledge-seeking motives, and to a partner located in a developed country.

Nonetheless it should be noted that, given this increased fragmentation and global dispersion of the R&D process, firms that engage in R&D alliances need to be able to efficiently perform the role of systems integrators, and this requires considerable knowledge if they are to monitor their partners (Brusoni et al., 2001). If they fail to do so, firms that rely too much on externalisation will face the risk of being hollowed out as a result of losing competitive edge in critical areas (Mudambi and Venzin, 2010). Thus, despite the flexibility gains that can be obtained, firms have to be careful of not being hollowed out when externalising knowledge-intensive activities. Thus, when deciding the scope of the alliance activity it should be noted that R&D alliances are not an alternative to in-house R&D, but complementary to it. R&D alliances do not replace the need for firms to undertake internal R&D activities; indeed, they enhance it. This is so because literature on innovation and technology transfer has shown that having access to external knowledge sources is not sufficient to learn from them, in order to do so, a firm needs to have the absorptive capacity required to assimilate, integrate and exploit that external knowledge (Cohen and Levinthal, 1990). Indeed, extensive literature has demonstrated that there is a positive relationship between external technology sourcing and internal R&D (Martínez-Noya and García Canal, 2011; Mol, 2005; Veugelers, 1997). More technologically capable firms are better equipped to avoid contracting hazards, as their internal technological capabilities allow them to select capable partners and to better monitor their behaviour (Mayer and Salomon, 2006). Thus, those firms lacking valuable technological resources will be less well-equipped to select an appropriate partner.

In addition, as many firms are nowadays the strategic centre of a wide variety of alliances (Kedia and Mooty, 2013) firms must have skills or innovation capabilities to be able to 'orchestrate' these disaggregated R&D processes (Kotabe and Mudambi, 2009). These innovation capabilities encompass several crucial and interrelated tasks, which include fostering, improving, and maintaining the relationships between the partnership through the processes related to R&D (Kale et al., 2002) and managing the knowledge flows between the partners (Mooty and Kedia, 2014). However, we are still not clear about how to measure or develop these orchestration capabilities (Asmussen et al., 2016; Larsen et al., 2013), and further research is needed on how firms can develop these capabilities to explore more effective ways to acquire, transfer, translate, transform and integrate external technological knowledge, especially in a portfolio of international R&D alliances (Van de Ven and Zahra, 2016). This will permit linking the alliance management literature with that of open innovation and offers promising opportunities for further research.

With whom do firms partner? The role of location

As it was referred to in previous sections, depending on the purpose of the R&D alliance and thus the type of complementary sought, firms can opt to partner with many different actors such as clients, suppliers, competitors or institutions (Miotti and Sachwald, 2003; van Beers and Zand, 2014) and each type of agent may offer different impacts on innovation outcomes (Belderbos et al., 2004; Nieto and Santamaría, 2007). However, although research on partner selection during alliance formation is extensive, it is also focused on some specific drivers. A meta-analysis of the literature of alliance formation identified trust, partner commitment, partner resource complementarity, and expected financial payoff as the key factors that influence partner selection and subsequent alliance performance (Shah and Swaminathan, 2008). Overall, firms tend to show a preference for selecting familiar partners (Li et al., 2008) because trust lowers the cost of negotiation, resolves conflict (Zaheer et al., 1998) and increases information sharing (Dyer and Chu, 2003). Through repeated ties, partners become familiar with each other and develop shared norms and a common understanding (Ring and Van de Ven, 1994). The relational view emphasizes that accumulated trust and knowledge with a specific partner is an asset that can generate rents as long as the relationship is maintained (Dyer and Singh, 1998; Madhok and Tallman, 1998).

As a consequence, when firms face the decision to choose between a familiar partner and a stranger, they tend to show a preference for allying with familiar ones despite the latter sometimes offering a priori better technological capabilities. This is so because even though the stranger partner may appear to offer upgraded technological capabilities, the lack of trust, and thus the behavioural uncertainty faced, requires more monitoring efforts in order to avoid the risk of knowledge leakage and opportunistic behaviour (Anand and Khanna, 2000; Ariño et al., 2001; Gulati, 1995; Zaheer et al., 1998). Indeed, Hoetker (2005) showed that as technological uncertainty increases, prior relationships take on greater positive significance relative to the importance of technical capabilities, as methods for facilitating smooth collaboration. In line with this, research on absorptive capacity have shown that prior interactions between partner firms can indeed reduce the causal ambiguity surrounding knowledge transfer and therefore facilitate more effective and efficient flows of technological knowledge from one partner to the other (Cohen and Levinthal, 1990; Kale et al., 2000; Mowery et al., 1996). However, this preference can lead to the so called paradox of embeddedness (Uzzi, 1996, 1997). Overcoming the limitations of contextually localised search (and thus accessing novel resources) is particularly important for innovation performance when the alliance activities to be undertaken involve exploration (Nooteboom et al., 2007). For developing truly radical innovations, overcoming path-dependent learning becomes crucial (Hart and Christensen, 2002). Over-reliance on trust and geographical proximity in selecting suppliers for R&D leads to an emphasis on incremental innovation (Bunduchi, 2013). Indeed, the positive effect of being embedded within a network shows an inverse U-shape and to maximise performance firms need to

combine strong embedded ties with familiar partners with weak ties with partners outside its network. However, little is known about under which circumstances firms are better off switching alliance partners to maximise innovation. Future research opportunities arise in analysing which should be the optimal degree of network embeddedness and analyse how these global R&D networks evolve over time, especially when a shift of technological paradigms takes place that changes the ''rules of the game'' within an industry.

Overall, firms need to seek a variety of technological inputs, and this means partnering with not just 'technology leaders'. If this were the case, asset-augmenting activities would remain the exclusive domain of only a handful of firms. As argued by Hagedoorn and Duysters (2002) while selecting partners that are well-established players in existing technologies may represent a profit maximising situation, it is optimal only in a static environment. In a dynamic environment, where there is a possibility of a technological change (or even a change in technological trajectories), having ties to a wide group of companies, including companies that have yet to demonstrate their value, represents a higher learning potential. At the technology frontier where dominant technological designs have not yet been determined and several potential options exist, it pays to have a number of overlapping, redundant agreements. It may be optimal to partner with all sorts of companies, even those without a demonstrated track record. For this reason, we argue that further analysis of how firms choose their alliance partners and especially how their alliance networks evolve over time when they face technological shifts deserves more attention and offers promising research opportunities.

The role of location

The decision of who to partner with goes hand by hand with the location decision of the alliance partner. This is so because the appropriability hazards perceived within an alliance are expected to depend not only on the characteristics of the transaction, but also on the location where the transaction occurs (Henisz, 2000; Santangelo et al., 2016). There may be some situations in which the location decision may come first, for example, for firms that want to form an alliance with a partner in a specific location to access some kind of location-specific advantage through the alliance partner. And, once decided the desired location, it will decide with whom to partner among the possible alternatives at that site. While, there are others in which it is more important to decide the type of partner that it is needed based on the technological capabilities it offers, independently of its location.

Indeed, apart from a preference for familiar partners, previous literature has found a preference for geographically proximate partners. Firms forming R&D alliances face high information costs due to information asymmetries (i.e. high costs of searching and evaluating alliance partners) and are thus subject to the risk of adverse selection (i.e. this is the risk of not selecting the optimal partner) (Reuer and Lahiri, 2014). Selecting a spatially proximate partner also offers the advantage of facilitating control, which becomes critical in R&D alliances, where misappropriation hazards are high (Li et al., 2008). As a consequence, R&D alliance formation tends to decline with geographic distance (Reuer and Lahiri, 2014). Aligned with this, a study by Capaldo and Petruzzelli (2014) on knowledge-creating R&D alliances shows that, although both geographic distance between allied firms and their affiliation with the same business group negatively affect the alliance innovative performance, the value of both direct and indirect prior ties between the exchange partners reduces the negative effect of geographic distance on R&D alliance formation. This is so because prior direct ties between the exchange partners, due to collaborations in the past, as well as indirect ties that they may have through common partners, both help reduce information asymmetries as well as the risk of adverse selection because they will have access to better information on the real resources and capabilities of the potential partner (Zaheer et al., 2010).

One stream of research that offers promising opportunities is the analysis of whether R&D alliances can substitute or complement collocation in a particular region. Previous research has found that firms collocate with other firms so as to be able to internalise location-specific advantages and enhance a firm's innovativeness, or avoid collocation so as to limit the possibility of unintended knowledge leakages (Alcácer, 2006; Narula and Santangelo, 2009, 2012). This is so because R&D activities are knowledge-based activities and tend to be location-bound, some locations may offer specialised knowledge or capabilities on a specific technological domain (Cantwell and Santangelo, 1999). In fact, it has been demonstrated that one of the key motives for firms to geographically distribute their R&D activities is the willingness to access knowledge spillovers (Feinberg and Gupta, 2004; Lahiri, 2010). When a firm wishes to benefit from location-specific assets, it can establish an affiliate in that location, because benefits generally accrue from physical proximity to the firm or cluster. However, it is also true that technology spillovers through collocation can be highly costly and require a long-term horizon, because linkages develop gradually over time. This means that in sectors where innovation is dynamic, a wholly owned subsidiary may not provide a fast-enough response, whereas the use of M&A may be even less attractive when the technological area where the complementary resources sought only covers a small area of the firm's interests. As a result, in order to tap these foreign external resources and access this specialised technological expertise, firms may find it convenient to ally with a partner located within such economies. It should be noted that international alliances can allow firms to access country-specific advantages embedded in their collaborative partners, and thus R&D alliances can be considered as a vehicle for tapping into the comparative advantages of foreign countries.

In this sense, recent literature has emerged focusing on analysing whether international R&D alliances substitute or complement collocation to internalise location-specific advantages (Narula and Santangelo, 2009). Such economic geography inspired studies share the emphasis that firms' innovative activities show a ''spatial stickiness'' and, for this reason, location is a primary determinant of the competencies a firm possesses (Iammarino and McCann, 2006). They suggest that location (or collocation) has an indirect

effect on the choice of partner because of the role of informal institutions in collaborations, which results in firms becoming embedded in relationships that firms have a natural tendency to perpetuate with other collocated firms and organisations. Firms belonging to the same spatially localised social network are ''likely to have a greater awareness of the rules, routines, and procedures each follows'' (Gulati, 1998: 304), which improves knowledge transfer and reduces the risk of opportunistic behaviours within the network. Indeed, there is evidence that shows that multinational firms locate asset-augmenting R&D facilities in offshore locations mainly with the intention of exploiting the benefits that derive from collocation (Blanc and Sierra, 1999; Criscuolo et al., 2005). Despite this, it is important to note that not all firms like proximity. Some firms tend to avoid collocation with the purpose of minimising undesired knowledge spillovers and leakage of valuable technological assets. Alcácer (2006) found that despite the higher concentration of R&D facilities compared to manufacturing or sales, more-capable firms collocate less than less-capable ones, regardless of the activity because more-capable firms have more to lose than to gain from clustering. For instance, more technologically advanced firms prefer to locate close to universities, and are less interested in locating proximate to rivals, whereas less competitive firms are more willing to collocate with other firms in the same industry (Alcácer and Chung, 2007). Narula and Santangelo (2009) shown that R&D alliances have the potential to act as a substitute for collocation where firms are not located in the same cluster, while at the same time these alliances enable firms to directly monitor knowledge exchange with their collocated partners and to access complementary capabilities, thus alliances acting as a complement to collocation. In addition, Martínez-Noya and García-Canal (2018) results suggest that allying with shared R&D suppliers that also serve competitors can mimic the advantages and disadvantages of being collocated with them, especially when the shared supplier is located in a country offering weak intellectual property rights protection. Nevertheless, more studies are needed in order to clarify under what circumstances R&D alliances complement or substitute collocation taking into account with whom the firm is allying, where and for what purpose.

In addition, promising opportunities arise from studies analysing the interplay between R&D alliance management and the IB literature. Each country or region offers different location-specific advantages, as well as imply different governance risks. However, as some IB studies have shown, firms differ in their attitudes towards risk depending on where the firm comes from, the type of firm, or its international experience (García-Canal and Guillén, 2008). For example, Cuervo-Cazurra (2006) suggests that firms who have been exposed to bribery at home may not be deterred by corruption abroad, but instead seek countries where corruption is prevalent. Thus, the country of origin of firms may shape the risks they perceive and thus the governance mode chosen for their R&D operations, as well as their alliance partner decisions (Awate et al., 2015; Narula and Sadowski, 2002). Indeed, research opportunities arise from studying how firms from emerging countries may differ in their R&D decisions as they may face and solve the alliance dilemmas described in a different way compared to firms from developed countries.

How do firms organise their R&D alliances? A shift to contractual and non-equity agreements

The alliance governance literature deals with how partners negotiating alliances choose a structure depending on the level of communication and coordination desired (Contractor et al., 2010). Previous research has tried to answer this question analysing which should be the most appropriate R&D alliance governance structure to be adopted by firms depending on several firm, technological or country factors. Nonetheless, despite the wide variety of R&D alliance forms, most previous empirical research during the 90s focused only on studying broad governance choices. On the one hand, certain scholars have focused on addressing whether and when firms should adopt contractual versus a hierarchical R&D modes (Carson et al., 2006; Hagedoorn and Hesen, 2007). Others have focused on the decision to opt for equity versus non-equity governance R&D modes (Contractor and Woodley, 2009; García-Canal et al., 2008; Osborn and Baughn, 1990; Oxley, 1997; Oxley and Wada, 2009). Although cooperation on R&D is not a new phenomenon, in recent decades there has been a clear shift towards an increasing use of contractual and non-equity agreements through the adoption of more open innovation strategies (Santamaría et al., 2010), so analysing how to manage this alliance portfolio deserves special attention. This means that studies should move from analysing broad governance choices to what drive firms to choose among different non-equity contractual modes (Martínez-Noya and Garcia-Canal, 2012).

A key question when negotiating and designing an R&D alliance is to determine the degree or communication and coordination that the partners want to have with each other to limit the risk of opportunistic behaviours while fostering innovation. Indeed, setting the right bandwidth or scope of interaction among partners can be very challenging for managers and is a research topic of high interest (Contractor et al., 2011; Grimpe and Kaiser, 2010; Oxley and Sampson, 2004; Tallman and Phene, 2007; Zhang and Baden-Fuller, 2010). This is so because the usually tacit nature of the knowledge exchanged within these alliances engender knowledge transfer problems. To mitigate those problems managers must adopt relationship-specific investments or knowledge management practices that are increasingly co-specialised as the degree of tacit knowledge and problem-solving complexity increases (Ashok et al., 2016; Heiman and Nickerson, 2004). Such investments and practices, like high bandwidth communication channels among partners that allow for higher intensity of communication and interaction, and communication codes that are increasingly co-specialised, are expected to help partners develop a better understanding of each other's cultures and management systems, thus enhancing coordination and conflict resolution (Heiman and Nickerson, 2004). In other words, through the establishment of these practices and investments partners try to establish ''ex ante'' the level of interaction and communication to exist among them. This knowledge (as well as the trust generated with it) is a valuable asset that can provide partners with a competitive advantage (Dyer and Hatch, 2006; Dyer and Singh,

1998; Madhok and Tallman, 1998; Mesquita et al., 2008). However, these relationship-specific investments, especially those that are of an intangible nature,[4] may act as a double-edged sword as they may give rise to contracting hazards (Martínez-Noya et al., 2013) and create an 'inter-organisational learning dilemma' (Larsson et al., 1998). This dilemma implies that although maintaining relationships that foster knowledge sharing in an open innovation context are beneficial (Chesbrough, 2003; Fey and Birkinshaw, 2005; Hoetker, 2005), extensive knowledge sharing may result in a loss of competitive edge due to outgoing knowledge leakages (Kale et al., 2000; Lado et al., 2008). These accidental knowledge leakages occur when a firm's employee accidentally exposes business-critical knowledge not meant to be shared with external parties (Ritala et al., 2015). For instance, trade secrets may spillover should employees reveal more than what is necessary. Accidental leaks can negatively moderate the positive effect of external knowledge sharing on innovation performance (Martínez-Noya and García-Canal, 2018; Ritala et al., 2015).

Therefore, when governing R&D alliances, it can be said that firms face the tension between knowledge sharing and knowledge expropriation (Heiman and Nickerson, 2004) because they need to maintain the necessary knowledge exchange to achieve their innovation objectives, while simultaneously being able to safeguard against the misappropriation of knowledge that these co-specialised investments make accessible (Grimpe and Kaiser, 2010; Oxley and Sampson, 2004; Ritala et al., 2015). How serious this threat is has been shown to be dependent on: (1) the extent to which the partner has access to complementary assets necessary to exploit that knowledge; and (2) the chances that the knowledge transferred within the alliance will leak to competitors through a common partner (Martínez-Noya and García-Canal, 2015, 2018). This fact could explain why within vertical R&D alliances some suppliers are willing to make unilateral commitments in the form of relationship-specific investments without economic safeguards (Kang et al., 2009). In effect, these agreements may evolve towards what Hamel (1991) calls learning races. In these alliances, each firm tries to speed up its learning rate to be the first partner capable of leaving the agreement, and in this way become the one with the strongest competitive position.

Research opportunities arise on analysing specific variables that may determine or moderate the optimal degree of scope or bandwidth to be adopted. This is so because although there is agreement on the benefits that accessing external knowledge may have on innovativeness, recent studies highlight the dark side of such openness to external agents, so more evidence on its effect on innovation is needed (Monteiro et al., 2017). Therefore, literature should move from analysing broad categories of governance forms to focus more on the interaction mechanisms or knowledge management practices to be adopted between partners so as to maximise value creation and appropriation of new technologies developed within the alliance. In this sense, a study by Contractor et al. (2011) has shown that variables related to: (1) the characteristics of the technology exchanged; (2) the coordination costs and risks faced (due to partner's behaviour as well as country risk); (3) agreement provisions (such as territorial restrictions, standardisation of contract terms or exclusivity of partnership); and (4) firm and sector characteristics (like firm experience with alliances and partner availability), may all have an effect on the optimal degree of alliance interaction.

In the same vein, studies focusing on variables that can act as moderators of the optimal bandwidth to be adopted to maximise innovativeness are needed. For example, because firms establish R&D alliances with a variety of partners (such as suppliers, competitors or universities) with different underlying motivational or strategic orientations, studying how the type of partner may moderate the optimal bandwidth to be adopted is another promising research line. Non-profits have different motivational or strategic orientation (Li et al., 2010) which means that they have lower incentives to apply the knowledge gained via the alliance to markets or products outside of the agreed-upon scope (Martínez-Noya et al., 2013). Similarly, sharing suppliers with competitors may aggravate the inter-organisational learning dilemma (Martínez-Noya and García-Canal, 2015, 2018). Aligned with this, another factor to be taken into account is how the number of partners within the R&D alliance influences governance choices and formalisation of contracts. Increasing the number of R&D alliance partners introduces more complexities to effectively manage the inter-organisational learning dilemma which implies that the optimal governance mechanism for multilateral R&D alliances may differ from that for bilateral ones. When cooperating with rivals, this learning dilemma reaches its maximum expression. Thus, it would be interesting to integrate competitive strategy considerations into alliance literature to analyse issues such as how firms compete for the value that they create within the R&D alliance, and how alliances with rivals emerge within industries and how these networks evolve over time (Contractor and Reuer, 2014).

Indeed, it should be noted that a firm's belonging to a particular network may act as a signal of its quality or reputation, thus reducing the risk of adverse selection. In this vein, a recent study by Choi and Contractor (2016) explored national, industry and firm factors that determine the selection of an appropriate R&D alliance governance mode. Using a sample of international alliance deals within the pharma industry they found that the likelihood of using a more-integrated alliance governance mode decreased as the difference or ''distance'' between nations of the partner firms increased in terms of human capital and cultural distance. While a greater geographic and institutional difference among partners was positively associated with the selection of more integrated alliance governance modes. Although the chronological order of the governance and location decisions is still a subject of debate, it is obvious

[4] Based on Zaheer and Venkatraman (1995), Martínez-Noya et al. (2013) posit that a distinction can be made among those relationship-specific investments of a tangible nature—physical specialised investments in tooling or equipment—and those more intangible or ''soft'' relationally-oriented investments—that is, investments in processes, procedures and people that are specific to the requirements of the partner. While the tangible ones are expected to generate hold-up hazards, the intangible ones give room for higher appropriability hazards.

that these two decisions are closely related. It should be noted that the location of the partner (whether the alliance partner is institutionally distant or not) may have a significant influence of the governance of the alliance. In this sense, the literature on cooperation highlights the importance of the institutional context where an alliance takes place. From a transaction cost approach, it is well known that sharing the same institutional context and a common organisational culture allows for more intensive communication between partners (Heiman and Nickerson, 2004). Therefore, research opportunities emerge to study how the location of partners influences the degree of communication to be adopted, and its impact on alliance innovativeness. Despite this, there exists scarce research dealing simultaneously with both decisions (Hätönen, 2009; Martínez-Noya et al., 2012; Nieto and Rodríguez, 2011; Rodríguez and Nieto, 2016). This is an important research gap. Future research needs to focus on combining both the IB and management streams of literature and elaborate on the factors that drive firms to externalise R&D services to a particular location and under what governance form. Although it is known that greater enforceability of contracts overseas has allowed for the increasing dispersion of these agreements (Narula and Hagedoorn, 1999), there is little empirical evidence explicitly analysing the determining factors of how the location of the R&D alliance partners influence the governance of these agreements.

The relevance of contracts

The high failure rate of alliances means that careful contract design is key. However, because designing and implementing contractual safeguards may be too costly, complex, and/or difficult to enforce, such clauses may not fully protect firms from misappropriation risks (Diestre and Rajagopalan, 2012; Dushnitsky and Shaver, 2009; Katila et al., 2008). For this reason, identifying which are indeed the most effective contractual clauses partners can use to protect them from these risks, while allowing them to achieve their innovative objectives, is indeed an important direction for future research.

A recent stream of literature has started to analyse contract provisions in more detail, and how these can influence the post-formation governance of the alliance and the exchanges between the partners (Ariño et al., 2014; Reuer and Ariño, 2007; Ryall and Sampson, 2009; Lumineau and Malhotra, 2011). To analyse how contract design shapes alliance management, new research opportunities arise in the use of new theoretical frames. Recent literature has emerged that calls for incorporating insights from psychology to study how firms can design and govern R&D alliances (Weber and Mayer, 2014). This is so because while transaction costs theory is very useful in illustrating how to avoid misappropriation hazards within these alliances, it is focused on preventing a negative behaviour (limiting opportunism and misunderstandings) while innovation is very much concerned about creating a positive attitude. In other words, transaction costs theory is less able to explain how to design contracts that can help foster a positive environment that enhances innovation.

Future research needs to acknowledge that contracts can do more than simply eliminate negative outcomes and can help set a frame that can encourage a positive outcome. For instance, regulatory focus theory suggests that individuals can choose one of two ways to pursue their goals. They can focus on achieving positive outcomes (a promotion focus), or by avoiding negative outcomes (a prevention focus) (Higgins, 1998). These different regulatory foci apply not only at the individual level, but also in exchange relationships (Das and Kumar, 2011). Based on this, recent works (Weber and Mayer, 2011; Weber et al., 2011) have shown how the framing of alliance contracts may shape alliance outcomes because they argue that contracts can play a role by helping set the frame under which the transaction will be executed. As argued by Wang and Rajagopalan (2014) the same reasoning can be applied to study the antecedents and consequences of managerial perceptions in the broader context of alliance capability investments. Those alliance relations perceived by firms as being filled with contractual hazards may tend to invest more in capabilities to prevent value capture by partners, while firms that have more positive expectations may invest more in capabilities to create value.

In addition, more research is needed to analyse how familiarity with the R&D alliance partner influences contract length and complexity because it is not at all clear whether trust and contracts are substitutes or complements. Some studies have argued that trust and familiarity with a specific partner leads to a lower need of designing complex contracts (Malhotra and Murnighan, 2002; Woolthuis et al., 2005). However, other studies state that familiarity can also lead to more complex and lengthy contracts (Ariño et al., 2014; Mayer and Argyres, 2004). Their argument is that familiar partners know each other better, so they are able to understand the most important contingencies that can occur, and they feel more comfortable providing contract details on how to allocate tasks and coordination provisions. In other words, through repeated ties partners learn to contract with each other.

We have a lot to learn about how alliances are negotiated, and the factors that matter in designing the negotiations. For instance, how the availability of other alternative suitable potential partners may influence the negotiation process (Contractor et al., 2011). Similarly, given that the value of the technological knowledge provided by the partners at the beginning of the alliance may erode over time, it would be very interesting to take a longitudinal perspective and focus on analysing how the power balance may shift between the R&D alliance partners over the course of their collaborative agreement.

The effect of R&D alliances on innovation and financial performance

In relation to the effects that R&D alliances may have on firms' performance, research has demonstrated that increasing the breadth of knowledge sources accessed positively impacts innovation performance (Faems et al., 2005; Leiponen and Helfat, 2010; Miotti and Sachwald, 2003). Each partner has been shown to offer different complementary knowledge and synergetic effects, so accessing and integrating knowledge and capabilities from diverse partners has been found to significantly contribute to innovation

performance (Belderbos et al., 2004; Nieto and Santamaría, 2007; van Beers and Zand, 2014). Furthermore, it has been found that more successful innovations take place when firms access knowledge from different technological domains and geographic locations (Ahuja and Katila, 2001; Laursen and Salter, 2006; Lavie and Miller, 2008).

In relation to this, less literature exists analysing the impact that R&D collaboration may have on the degree of novelty of the innovations achieved. For example, Nieto and Santamaría (2007) found that collaboration with suppliers had the greatest impact on the novelty of the innovation, followed by collaboration with clients and research organisations; while collaboration with competitors had a negative impact. In this line it has been shown that collaborating with prospective users contribute more to radical innovations, while collaborating with existing users contribute more to more incremental product innovations (Ashok et al., 2016). Un et al. (2010) contribute to this line of research suggesting that it is the ease of knowledge access, rather than breadth of knowledge, what appears to also drive the success of R&D collaborations for product innovation. Similarly, the location of the alliance partner is also expected to shape innovation performance because partners located in foreign regions are embedded in different national innovation systems having thus access to location-specific resources (Miotti and Sachwald, 2003). Indeed, having geographically diverse partners can help firms to better adapt their products to foreign markets, which contributes to innovation performance (Lavie and Miller, 2008; van Beers and Zand, 2014).

Although more extensive literature has analysed the impact of collaboration on innovation performance, less empirical evidence is found in relation to the effects that R&D alliances may have on firms' financial performance. In this sense, Belderbos et al. (2004) analysed the effect of collaboration with different types of partners on labour productivity and productivity in innovative (new to the market) sales and they found that cooperation with both competitor and supplier focus on incremental innovations, improving productivity performance. Cooperation with universities and competitors contribute to create innovations generating sales of novel products, while customers and universities are important sources of knowledge for firms pursuing radical innovations and facilitate growth in innovative sales. Similarly, Surroca and Santamaría (2007) also found that vertical, horizontal or institutional cooperation have different impacts on firm performance, and shown that innovative results positively impact firm performance. In particular, they found that while innovation results mediate the relationship between institutional cooperation and firm performance, vertical cooperation has both a direct and an indirect effect on performance. Very interestingly, they found that horizontal cooperation (i.e. with rivals) had a negative effect on innovation results as well as on firm performance. This result can be however explained by Santamaria and Surroca (2011) as collaboration with rivals is usually motivated by the desire to carry out pre-competitive research, which may not necessarily have a direct impact on innovation performance.

Nevertheless, we believe that this relationship between diversity and performance is not so straightforward. It should be noted that although having more diverse partners can enhance potential learning benefits, the coordination costs and the complexity of managing the firm's R&D alliance portfolio are expected to be also greater. This means that, as argued by Jiang et al. (2010), firms should manage their alliances with a portfolio perspective, trying to maximise resource and learning benefits by allying with a variety of partners in various value chain activities while minimising managerial costs through a focused set of governance structures. Therefore, in order to be able to take advantage of partner diversity, firms should have the required capabilities in terms of prior experience in alliances, technological capabilities, or appropriate IT applications to facilitate collaboration (Jiang et al., 2010). However, more studies are needed to study the effect of other variables that may moderate the relationship between partner diversity and innovation and financial performance, such as those related to the firms' strategy, institutional environment, or sector. For example, a recent study by Cuervo-Cazurra et al. (2017) suggests that the relative importance of diversity and control of knowledge on innovation performance depends on the sources of finance, and that alternative sources of finance moderate the relationships: internal funds strengthen the impact of R&D sources with more diversity of knowledge on the sale of new products, while external funds strengthen the impact of R&D sources with more control of knowledge.

Over time, firms combine different exploration or exploitation motivations when designing their R&D alliance portfolio, which means that depending on the firms' motivations, the level of partner diversity and optimal configuration of the R&D alliance activity may change (Santamaria and Surroca, 2011). Thus, more studies are needed to understand how the type of partner diversity (functional, geographic, network position, technological leadership, etc.) and governance structures should evolve over time to maximise both innovation and financial performance as the firms' technological orientation between exploitation and exploration motivations changes.

Conclusion: implications for future research

Research on R&D alliances has been focused on broad topics such as discrete governance choices decisions, motives for collaboration, location decisions, or partner selection decisions. However, the review of the literature allowed us to identify some new trends on R&D cooperation during these last decades that suggest that the most interesting research opportunities result from the interlinkages between these questions. To summarise, we have seen a dramatic increase of non-equity modes of governance for technological activities (Narula and Martinez-Noya, 2015; van Kranenburg et al., 2014). At the same time, alliances have become dispersed worldwide, formed with partners in both developed countries as well as in developing ones (Martínez-Noya et al., 2012; Nieto and Rodríguez, 2011; Zhao, 2006). They also involve more complex activities that require a higher intensity of cooperation (Contractor et al., 2010). All these trends increase the complexity of effectively managing the R&D alliance portfolio, and thus the likelihood of alliance failure. Therefore, it is not a surprise that despite the potential benefits that R&D alliances may offer, we have seen that there are many firms that are not able to reach the expected

objectives because they do not know how to manage these increasingly complex agreements surrounded by high levels of technological and behavioural uncertainty (Lhuillery and Pfister, 2009; Lokshin et al., 2011).

Due to this changing landscape that adds complexity to the phenomenon, we argue that future research on R&D alliances require us to move from broad research questions towards analysing the details and development of these agreements by taking a multidisciplinary approach. Overall, throughout the paper we identified different areas that offer promising opportunities for future research. However, among all the opportunities identified, we would like to summarise the following key ones that in our opinion offer the most interesting opportunities:

- Integrate theories from behavioural sciences to better understand the role of managers' perceptions on different R&D alliance decisions. Recent scholars have considered psychological or behavioural disciplines (Das and Kumar, 2011; Tyler and Caner, 2016). Future research can continue with this stream by considering managers' expectations or aspirations in R&D alliance formation decisions.
- Understand at the transaction level how the scope of collaboration is determined and the effects of this decision on the selection of partners and governance modes. Previous studies such as Li et al. (2008) or Martínez-Noya and García-Canal (2018) provide good examples of how the characteristics of what is externalised may influence partner decisions. However, more studies are needed to shed more light on the interrelationship among these questions.
- Analyse how the location of the partner influences the governance of the agreement, and/or the type of partner to be chosen. We consider that more works are needed from IB scholars following works such as those of Gooris and Peeters (2016), Hagedoorn et al. (2005) or van Kranenburg et al. (2014), taking a multidisciplinary approach.
- Analyse whether international R&D alliances substitute or complement collocation to internalise location-specific advantages. Despite some studies have considered this line of research (Narula and Santangelo, 2009), more investigation is needed to understand in which circumstances they function in one way or another. Aspects such as who is the partner, where the partner is and the objective of the alliance may help to advance the literature.
- Study how contracts shape the behaviour of partners, and thus the performance of these alliances. As argued by Contractor and Reuer (2014) or Weber and Mayer (2011), contract design can indeed have an important influence on the behaviour of the alliance partners, however there is still an important gap in the literature on their effect on R&D alliances.
- Explore more effective ways to acquire, transfer, translate, transform and integrate external technological knowledge for multiple and diverse partner, especially in international alliances. More studies are needed to better understand how firms can effectively ''orquestrate'' their dispersed R&D activities, for example linking the R&D alliance literature with that on open innovation (Van de Ven and Zahra, 2016).

Obviously, addressing all these questions implies changes both in relation to the theories that we need to apply, as well as in the type of data that we need to gather. On the one hand, the future of this research field requires integrating insights from different disciplines, especially from psychological or behavioural theories to more traditional managerial perspectives to analyse how more microfoundational aspects influence R&D alliance decisions. In addition, promising opportunities arise from studies analysing the interplay between R&D alliance management and the IB literature. On the other hand, the shift towards the analysis of the details dealing with the structuring, governing and functioning of R&D alliances means that empirical studies need to gather more ''micro'' data at the transaction or dyad level, and/or longitudinal data to allow for the understanding of how partnerships evolve over time. Studies on R&D alliances tend to use large alliance databases. Each database has its unique advantages and disadvantages—see Schilling (2009) for an extensive review—each of which introduces its own biases to the analyses. For instance, research on R&D alliances has traditionally focused on very broad governance choices because of the limitations due to the way in which these databases were originally designed. However, scholars are nowadays encouraged to complement these data containing public announcements with additional data sources stemming from primary sources such as surveys, and/or use secondary data offering richer information on the details of the agreements. Indeed, accessing primary data is the only way to analyse how managerial perceptions may influence their alliance decisions. It is obvious that collecting these data is very difficult and thus becomes a huge challenge for researchers.

Finally, it should be acknowledged that given the highly dynamic nature of the technological landscape, and because different contexts may offer different challenges or opportunities for value creation or appropriation, firms need to constantly update and adapt their alliance capabilities (Wang and Rajagopalan, 2014). Further studies can deepen on the understanding of how to develop these dynamic alliance capabilities for R&D partnerships so as to maximise value creation and appropriation over time. In effect, effectively managing this trade-off has been found to be especially relevant and at the same time challenging within R&D alliances.

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