From Knowledge Base to Alliance: The Strategic Significance of Knowledge Depth and Breadth in Biotechnology

**Abstract**: This paper offers a new theoretical framework that explains the association between a biotechnology firm’s knowledge structuration- i.e. depth and breadth of knowledge- and its strategic alliances: First, knowledge depth and breadth each play distinctive roles in alliance relationships and this role varies depending on the goal of the alliance and the type of partner. Second, the firm’s participation in various forms of alliances implies different learning processes between the partners and therefore, in time, it affects the evolution of its knowledge base structuration. We offer research propositions that encompass this ‘interplay’ between knowledge structuration and the firm’s alliance activity.

Keywords: Knowledge strategy, technology alliance, depth, breadth, biotechnology

1. **Introduction**

The four decades since the first breakthroughs in biotechnology till date have witnessed an enormous rise in R&D-related activities of a diverse set of players ranging from small and large dedicated biotechnology firms, universities and research centers, and even established firms from other industries (Huggett, 2013). Meanwhile, management scholars have investigated the impact of size, value, and quality of a focal firm’s knowledge base on variables such as alliance formation, innovation or performance (e.g. Coombs, Mudambi, and Deeds, 2006; Gopalakrishnan, Scillitoe and Santoro; 2008; Harrigan, 1985; Higgins and Rodriguez, 2006; Pisano, 1990).

Despite the numerous studies examining the dimensions of an organization’s knowledge base, *knowledge structuration*, or the way a firm’s knowledge portfolio is structured *across* and *within* technology domains (i.e. *breadth* and *depth*, respectively), has received far less attention (George, Kotha and Zheng, 2008). Breadth refers to the technological diversity or the scope of technology domains, while depth refers to the accumulated expertise and specialization in a single technology domain. During the recent years, however, researchers have contributed to our understanding of how knowledge structuration relates to firm and alliance outcomes (e.g. George, Kotha and Zheng, 2008; Kotha, Zheng and George, 2011; Zhang, Baden-Fuller and Mangematin, 2007; Zhou and Li, 2012). Also, while many studies have explored the knowledge-based resources of the firm and their association with alliance relationships (e.g. Higgins and Rodriguez, 2006; Nielsen and Nielsen, 2009; Rothaermel and Boeker, 2008), theoretical development on how knowledge structuration relates to strategic outcomes at both firm and alliance-level is still somewhat scarce (Zhang and Baden-Fuller, 2010).

Notwithstanding, the existing literature still fails to view knowledge structuration as a feature that both affects and is affected by alliances: First, if a young biotechnology firm has a particularly broad knowledge base, this might have different implications for its subsequent alliance activities, than if it had a particularly deep knowledge base. Second, throughout the years firms engage in different types of strategic alliances that, as we will elaborate, involve different learning processes and varying degrees of knowledge transfer among partners. Our contention is that these differing learning processes, in turn, can each leave an imprint on the firm’s knowledge base and the way it is structured across or within domains (breadth or depth, respectively).

The literature considers two broad categories of alliances based on the primary motivation of the participating firms: ‘Learning’ alliances are motivated by the firm’s desire to *learn* new knowledge from the partners and internalize this knowledge to build up its own internal competencies. ‘Access’ alliances, on the other hand, are motivated by the firm’s desire to merely *access* the partner’s knowledge or other complementary assets (Lavie and Rosenkopf, 2006), without an emphasis on internalizing this knowledge into the firm’s existing knowledge base. Alliances that involve learning new knowledge are often characterized with a closer interaction among partners and a more intensive transfer of knowledge, when compared to alliances that are primarily concerned with accessing existing knowledge (Grant and Baden-Fuller, 2004).

For example, Biogen, a Massachusetts-based biotechnology firm, intensified its learning strategy through alliances starting from 1995, in such a way that in the ten years after that it entered into 43 ‘learning alliances’, as opposed to only 9 such alliances in the ten years leading to that date. Meanwhile, the number of ‘access alliances’ in which the firm participated in the two periods exactly doubled, from 35 to 70. The number of patents that Biogen was granted in each period[[1]](#footnote-2) raised from 139 to 412 as it dedicated more to learning alliances. Moreover, the company broadened its range of expertise by entering into fields such as anti-infectives, pulmonary-allergy, dermatological and anti-inflammatory[[2]](#footnote-3).

Broadly speaking, the focal biotechnology firm can engage in partnerships with two types of partners: universities or research centers, on the one hand, and other firms on the other hand. While allying with both type of organizations is common, making this distinction is important for the degree of knowledge that can be transferred within the alliance. Unlike firms, universities are not primarily seeking economic rent, meaning that they do not share the same dominant logic with biotechnology firms. We will later discuss how this implies that there are less barriers to the transfer of knowledge in university-firm partnerships.

Our study therefore contributes to the literature on the management of technology and alliances in two ways: First, we offer a theoretical development to explain how the depth and the breadth of knowledge relates to a firm’s alliance activity. We then examine how the evolution of a firm’s knowledge structuration can be a function of its engagement in different types of alliances. We build on existing literature when explaining the relationship between knowledge structuration and alliances; but depart from and adds to this literature when viewing the *evolution* of a firm’s knowledge base structuration. This holistic view paves the way for studies of knowledge base as a ‘moldable’ component that is continuously evolving in a dynamic manner. Second, our study contributes to the literature on knowledge strategy as the four different groups of firms that we identify represent different settings in which a given firm operates, and they each lead to unique managerial implications. For example, firms with high depth and low breadth face opportunities and challenges different than those with low depth and high breadth, even if the two companies are comparably similar in other aspects.

The paper proceeds in the following way: In section 2 we first discuss the theoretical foundations of our research and then, building on these foundations and previous theoretical and empirical research, we further develop the theory that encompasses knowledge depth and breadth in biotechnology industry and related alliances. Section 3 offers research propositions dealing with differences among firms in different knowledge groups as well as the reciprocal relationships between knowledge structuration and the firm’s alliance activity. Sector 4 presents a discussion of the main ideas developed throughout this study, as well as conclusions and future lines of research.

1. **Theory Development**
	1. **Local and distant search, depth and breadth of knowledge**

In theory, all innovations are based on some sort of knowledge recombination (Kaplan and Vakili, 2015), because new knowledge is created by unique recombination of existing repositories (Henderson and Cockburn, 1994; Schumpeter, 1934). Previous studies have repeatedly found strong evidence for various forms of recombination as the main mechanism leading to breakthrough innovations (e.g., Fleming, 2001; Hall, Jaffe, and Trajtenberg, 2001).

Narrow recombination of similar knowledge indicates what researchers call “local search”; whereas recombination of distant or diverse knowledge represents “long-jump search” (e.g. Gavetti and Levinthal, 2000). Local search does not span technological boundaries and it may or may not span organizational boundaries. Long-jump search necessarily spans technological boundaries while again it may or may not span organizational boundaries (Rosenkopf and Nerkar, 2001). It follows that “local search” contributes to the depth of a firm’s knowledge as it involves seeking for new knowledge in the existing knowledge domains, while “long-jump search” expands a firm’s breadth of knowledge base by opening up new domains to the firm.

Many scholars have emphasized the essential role of a “deep” knowledge and found that immersion in a particular domain is required in order to produce novelty (Csikszentmihalyi, 1996; Lin and Wu, 2010). Zahra and George (2002) found that radical innovation needs in-depth knowledge in a specific field. Deep knowledge enables a firm to understand causal linkages between the old components (March, 1991), and furthermore, to make new combinations from old components by understanding the limitations of existing components from repeated use (Zhang and Baden-Fuller, 2010). Deep understanding in one particular area is thus beneficial not only by providing expertise in solving one specific type of question, but also by supporting the engagement of that knowledge in exploring new applications and technological opportunities (George, Kotha and Zheng, 2008). Quite on the contrary, however, most of past research on recombination views “deep” knowledge in a given domain as a factor that diminishes creativity by locking in scientists into one way of thinking (Ahuja and Lampert, 2001). Tripsas and Gavetti (2000) found that deep knowledge in a specialized field may trigger cognitive inertia, which means that the firm constraints itself to the existing market or the established technology.

As to the “breadth” of knowledge base, researchers have found that firms with diverse knowledge domains are more likely to generate cutting-edge ideas and novel combinations of knowledge components (e.g. Taylor and Greve, 2006). A firm with a broad knowledge base is in a better position to detect remote technological or market opportunities for its breakthrough innovations, since it can better understand new information (Chesbrough, 2003). Impactful innovation requires a broad search beyond the existing domains of expertise, and is often the result of the recombination of knowledge from various kinds and fields (Taylor and Greve, 2006). Combining knowledge from long-jump search is more likely to produce inventions that break from the existing technological and scientific models and ultimately become highly cited (Kaplan and Vakili, 2015). In spite of these positions, however, other researchers posit that although broad knowledge can stimulate a variety of ideas, in the absence of sufficiently deep knowledge and expertise those ideas are more likely to touch on shallow surfaces and bring about incremental, not radical innovations (Laursen and Salter, 2006; Zhou and Li, 2012).

Taking patents as measures of innovations, empirical research has investigated how the depth and the breadth of knowledge leads to different innovative outcomes. For example, by analyzing the US patent record in biotechnology from 1976 to 2001, Arts and Veugeler (2013) show that highly impactful breakthroughs are results of wide recombination and broad knowledge bases. In another study, Kaplan and Vakili (2013) analyze nanotechnology patents and find that those patents which generate new topics are likely to be associated with experienced researchers exploring one or a small number of domains in-depth. They suggest that novelty is produced by experts who “draw on a single domain in a practiced manner” (Taylor and Greve 2006, p. 727), “while the most useful (highly cited) patents are the product of broader recombinations”.

* 1. **Learning vs. access alliances**

As we mentioned, a firm's choice of the type of collaboration to take part in can be distinguished by its motivation to either acquire and learn new knowledge which is generated by exploring new capabilities, or to merely access the partners knowledge and exploit complementarities (Koza and Lewin, 1998). Interestingly, the biotechnology sector encompasses alliances with both types of knowledge-sharing: First, there exist learning alliances, which are entered into with the motivation to discover something new. These partnerships focus on the ‘R’ in the research and development process (Koza and Lewin, 1998) and are characterized by a high level of interaction between partners and consequently considerable transfer of knowledge (Grant and Baden-Fuller, 2004). For example, in many alliances formed between biotechnology firms and research centers or universities the firm needs to absorb and learn its academic partner’s knowledge. Its intention is to acquire basic knowledge that can be used to create novel molecular entities that are later entered into development and regulatory process (Rothaermel and Deeds, 2004). Generally speaking, collaborative research projects -whether with other firms or with universities- are clear examples of ‘learning alliances’ where both partners are involved in the performance of the project. In biotechnology, these are often alliances with a joint research and development component and focused on basic research, drug discovery and development.

 Second, the industry is also scene to thousands of alliances where knowledge-access, rather than learning, is the main intention of the partners. These alliances focus on the ‘D’ in the research and development process (Koza and Lewin, 1998; Teece, 1986). Motivations for ‘accessing’ partner’s knowledge can be found in licensing agreements such as one between a biotechnology firm and more established pharma partner. The biotechnology firm has distinctive technological competencies (related to a product or drug candidate) and the large pharma partner has strong marketing resources and regulatory management capabilities. Hence, they both benefit by pooling complementary resources together and accessing each other’s assets. The pharma partner is not necessarily interested in acquiring all the components of knowledge from the biotech partner, rather it is interested in exploiting those capabilities towards commercial goals. Other examples are licensing agreements or fee-for-service agreements between research institutes and biotechnology or pharmaceutical firms. For example, the firm might choose to perform clinical trials and analyze trial data for its internally-developed drugs through agreements with universities (Bercovitz and Feldman, 2007). Generally, in biotechnology industry, access alliances are typically those targeted towards commercialization and are related to clinical trials, regulatory processes, marketing and sales.

Although a collaborative research agreement increases the potential for discovery and learning, it can also increase the potential for disputes over control and ownership of intellectual property generated through the partnership (Bercovitz and Feldman, 2007). Contractual rights can be negotiated before the alliances, if the results are somewhat predictable in advance. That is the case with most ‘access’ alliances set to exploit complementarities. But in ‘learning’ alliances, the exploratory nature of the project makes it difficult to specify and price property rights ex ante as the intellectual property does not yet exist (Mowery and Rosenberg, 1989).

The distinction between learning versus accessing knowledge in alliances is critically important for the evolution of the alliance partner’s knowledge bases. Past research has found patterns of convergence of knowledge bases among partners engaged in learning alliances, and divergence among those involved in accessing alliances (Mowery, Oxley and Silverman, 1996). While in practice there are much more ‘access’ alliances than ‘learning’ ones (Grant and Baden-Fuller, 2004; Koza and Lewin, 1998; Rothaermel and Deeds, 2004), from a theoretical lens they each deserve particular attention as they imply different degrees of partner interaction and knowledge transfer. This means depth and breadth of the focal firm’s knowledge can play differing roles in each type of alliance, and each type of alliance impacts the focal firm’s knowledge structuration differently.

* 1. **Alliances with other firms vs. universities**

In addition to the level of interaction between partners and the intensity of knowledge transfer, another distinction among alliances is whether they are between firms or between a firm and a university. A focal biotechnology firm can partner both with other firms and with universities, while these two types of organizations differ substantially in their scientific foundations and dominant logics (Powell et al, 2005).

Because universities have limited incentives to act opportunistically, they may be preferred as research partners when firms perceive appropriability concerns. Disputes over intellectual property rights and fear of partner’s opportunistic behavior are more pronounced in interfirm alliances than in firm-university partnerships because in the former type of collaboration both partners are in a position to exploit potential commercial value. As entities seeking economic rent, all types of firms in biotechnology industry share a similar dominant logic: taking scientific knowledge to commercial ends (Al-Laham, Amburgey and Baden-Fuller, 2010).

In addition to lacking complementary assets to compete directly in the market, universities are the largest performers of exploratory, basic research and home to new discoveries. Because they operate far from the competitive demands of the industry, they may search more broadly than firms, and hence they can offer a more unique set of know-how. Surveying a sample of North American executives, Bercovitz and Feldman (2007) found that two-third of all firm-univeristy alliances engaged exploration of new knowledge.

Until now, we have discussed two sets of distinctions in alliances: Learning versus access alliances, and firm partner versus university partner. Table 1 summarizes the two sets:

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1. **Knowledge Structuration and Biotechnology Alliances**

The question of how a technology firm should structure its knowledge base is especially salient in biotechnology industry, where many start-ups and young firms, resource-constrained by definition, need to enter into or remain in those new technological niches or domains that are expected to generate payoffs in the future (George, 2005). “The resource-constrained nature of start-ups is likely to exert a disproportionate influence on entry to new technological niches” (George, Kotha and Zheng, 2008).

Imagine two hypothetical biotech companies: Firms A and B, each having their technology resources represented by 100 patents. Firm A has knowledge and expertise in three domains of biotechnological knowledge, with a profile of 80–10–10 patents granted in these three domains. Firm B, again with knowledge and expertise in the same three classes, i.e. with the same knowledge breadth, has a profile of 33–33–34. For example, for a larger pharmaceutical firm which acts as the client of the technology developed in the biotech partner company, the firms A and B are essentially different, even if the size of their knowledge bases or the number of their patents are equal (Zhang, Baden-Fuller, Mangematin, 2007). Unlike firm B, firm A has focused its patenting activity in a particular knowledge domain and can signal the pharma partner that it has got specialized expertise in a specific domain.

Similarly, firm A (with 100 patents structured as a portfolio of 80-10-10) is not the same as another firm, say firm C, which possesses the same number of patents but with a portfolio of 80-5-5-5-5. The two firms are not equally broad in their knowledge base, although both of them are known for possessing particularly deep knowledge in a given technology domain. For example, if they engage in a learning alliance and aim to acquire partner’s knowledge, they will face different learning processes as firm C is technologically broader than firm A and its prospect of knowledge overlap with the partner is better.

* 1. **Biotechnology firms in four strategic knowledge groups**

Considering breadth and depth as two exclusive dimensions of a firm’s technological knowledge base; a given (technology-based) firm can be said to belong to one of the following four groups, when compared to other firms in the industry: 1) ‘Ocean’ firms: those which are both broad and deep in their technological resources. These firms have developed their technological expertise in a wide and diversified range of areas, while they are also specialized in each of those technology classes. 2) ‘Gorge’ firms: those that possess a deep but not broad knowledge base. Being deep but lacking breadth makes these firms resemble to a gorge. 3) ‘Lagoon’ firms, on the other hand, are those firms that have developed their technological resources over a broad range of areas, but are not deeply specialized in any of them. They are thus similar to a lagoon that is known primarily for being broad rather than deep. 4) Finally, ‘Pond’ firms have technological expertise only in a small number of knowledge domains, and they are not profoundly specialized in any of them. Figure 1 illustrates the four groups:

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For a firm to gain a broad knowledge base, it needs to continuously explore diverse knowledge areas through long-jump searches. Similarly, having a deep knowledge base requires constant exploration of new knowledge while digging in one or few technological areas through local search. Both of these searching activities are time-consuming and work in a path dependent, accumulative fashion.

Because ‘Pond’ firms are neither deep nor broad in their technological knowledge, we expect that these must be relatively younger firms still moving towards broadening and/or deepening their technological resources. Pond firms are expected to go out of business if they fail to broaden or deepen their technological resources as they grow. That is because, in order to survive, these firms need to acquire financial capital, legitimacy and vertically related facilities often through alliances (Arora and Gambardella, 1990; Liebeskind et al. 1996). Dedicated biotechnology firms that have eventually died are shown to have had lower odds for forming alliances during their life course (Oliver, 2001). If the technological resources of the firm remain shallow (not deep) and narrow (not broad) over time, attracting alliance partners and the related complementary assets will become unlikely.

The exact opposite of a Pond firm is an ‘Ocean’: If a firm is both deep and broad in its technology resources, this signals earlier continuous engagement in R&D activities and the accumulation and routinization of technological knowledge over a long period of time. Scholars have long studied two main phenomena that happen as firms age: They become more efficient in learning from cumulative output, and they also become more rigid towards change as a result of routinization and ‘senescence’ (Cohen and Levinthal, 1990; Kotha, Zheng and George, 2011). We expect that in an industry as volatile and rapidly changing as biotechnology, even older firms learn to adapt to change, fight rigidity and cope with technological uncertainty through the various types of agreements such as acquisition, in-licensing and alike. On the other hand, increased efficiency in learning piles up expertise and equips the older firm with a deep knowledge base. Similarly, a firm’s resource endowment, especially its slack resources, encourages it to explore new areas for growth (Penrose, 1959) and gain breadth of knowledge as well. Accumulation of expertise in a given area, and diversification into new areas, is only possible throughout years of activity.

Above we discussed Pond and Ocean firms. To discuss Gorge and Lagoon grups, In figure 2, we illustrate an example of the case when the same amount of input can be used differently: To broaden the knowledge base, or merely to deepen existing knowledge domains (Wang and Tunzelmann, 2000). Although firms G (a hypothetical Gorge firm) and L (a hypothetical Lagoon firm) both have 10 patents, the structuration of these patents across technology classes makes them essentially different. However, firm O (a hypothetical Ocean firm) is bound, by definition, to have more patents than others (more than 10). Similarly, firm P (a hypothetical Pond firm) has less than 10 patents. It is reasonable to expect that no firm starts as an “Ocean” firm, and most firms perhaps start in the “Pond” group. Then, through a process of learning, absorbing and integrating knowledge, they might follow a “focus” strategy and move to the Gorge group, or they might adopt a ‘diversifying’ strategy and move to Lagoon group. Only highly successful firms can expand both dimensions of their knowledge bases above those of the average firm and become Oceans.

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* 1. **Research Propositions**

Many biotechnology firms use alliances for ‘importing’ needed capabilities, learning, complementary assets and financial capital while they mainly ‘export’ their R&D capabilities (Deeds and Hill 1999). The main motive for a resource-constrained biotech firm to enter ‘access’ alliances, e.g. with larger firms, is to acquire financial capital, and access the partner’s regulatory management and marketing capabilities (Gopalakrishnan, Scillitoe & Santoro, 2008). However, this implies that such a firm, typically being the smaller partner and resource-constrained, will inevitably be over-reliant on external resources in the new product development process, leaving it open to be undervalued and to the risks of having its core knowledge assets expropriated (Rotahermel and Deeds, 2004). Empirical research has found evidence of these problematic outcomes in small firm-large firm alliances where the latter is the financier of the R&D project (e.g. Lerner, Shane and Tsai, 2003; Rothaermel, 2001).

As it experiences internal growth, the firm develops its own resources to gradually reduce its dependency on other organizations (Pfeffer and Salancik, 1978). The gradual tendency to substitute internal resources for external ones as the technology venture grows are documented both in empirical and theoretical works by earlier researchers (e.g. Myers and Majluf, 1984; Rotahermel and Deeds, 2004).

An Ocean firm is, as discussed above, a relatively established firm with profound expertise over a wide range of technological areas. Because of its rich internal resources, such a firm is expected to pursue vertical integration and in-house development instead of an alliance strategy, so that it is better able to protect itself against expropriation risks, ownership right concerns and undervaluation. We expect the Ocean group to engage in less firm-firm alliances than the other three groups:

**Proposition 1a:** *Among the four groups, Ocean firms exhibit the lowest tendency towards engaging in alliances with other firms.*

However, we cannot suggest a similar proposition for firm-university alliances. Universities and research centers are non-for-profit entities that often provide basic and pre-competitive research to complement and supplement a firm’s shorter term and more applied R&D efforts (Jiang, Tao and Santoro, 2010; Santoro and Chakrabarti, 2002). Although appropriability disputes are common in firm-university partnerships as well as firm-firm collaborations, the former implies a different setting as the emphasis on making profits are much weaker for universities than for firms and a minor objective compared to the university’s primary functions of education, research, and service (Bercovitz and Feldman, 2007). Therefore, a mature biotechnology firm does not have the same reasons to be less inclined towards university alliances as it has towards firm alliances. As universities are the main sources of basic research and scientific discoveries, learning through academic alliances can guarantee the focal firm’s sustainable innovation and adaptation to technological change, no matter the age of the firm or the structuration of its knowledge base.

**Proposition1b:** *Firms in all the four groups exhibit an equal tendency towards engaging in alliances with universities.*

Past research has found a variety of factors that affect the ease of knowledge transfer between alliance partners, e.g. knowledge tacitness and embededness (Nielsen, 2005; Simonin, 2004), governance mode of alliances (Fey and Birkinshaw, 2005), and knowledge similarity or diversity between alliance partners (Lin and Wu, 2010). From the viewpoint of the receiving side of knowledge flow (Foss and Pedersen, 2004), the most critical factor influencing the effectiveness of learning from an alliance partner is what most researchers call ‘absorptive capacity’ (Cohen and Levinthal 1990; Lane and Lubatkin, 1998; Zahra and George, 2002). Absorptive capacity is dependent on the level of prior related knowledge (Cohen and Levinthal, 1990: 128). In the context of interfirm collaborations, many studies have shown that the ability to absorb knowledge from partner increases with the knowledge overlap or relative knowledge base of partners (Lane and Lubatkin, 1998; Mowery, Oxley and Silverman, 1996; Stuart, 1998). Cohen and Levinthal (1990) argued that knowledge broadness increases ‘absorptive capacity’ and facilitates the innovative process by enabling organizations to make novel associations and linkages. Investment in breadth of knowledge determines the extent to which knowledge will be overlapping with a potential partner, because it will increase the prospect that knowledge will relate to what is already known (Van Wijk, 2003: 72). That means, investment in broadening the knowledge base builds absorptive capacity and positions firms to take advantage of cross-boundary exploratory alliances (Bercovitz and Feldman, 2007).

The above is true for learning from both types of partner, whether firm or university. But the importance of breadth of knowledge is even more acute in the case learning alliance with universities. The knowledge from universities is less targeted to the firm’s practical needs, therefore the firm’s internal R&D becomes more important in recognizing the value, and then assimilating and utilizing outside knowledge (Cohen and Levinthal, 1990).

To sum up, in a learning alliances where the focal biotech firm serves as the ‘receiving end’ of the transfer of knowledge and technology, the breadth dimension of its technological knowledge plays a crucial role on how effective the knowledge is transferred and how much the firm benefits from the alliance.

**Proposition 2:** *In learning alliances, Lagoon firms are in a better position than Gorge firms to acquire partner’s knowledge.*

We now shift our attention to access alliances. As we said, biotech firms often provide technology for their typically larger and more established partners- the clients of the technology. A clear example is when large pharmaceutical companies look for specific drug targets or group of potential drugs (Dunne, Gopalakrishnan, Scillitoe, 2009). These firms typically have a broad knowledge base and are not specialized on a particular set of technology and products (Zhang, Baden Fuller, & Mangematin, 2007). Therefore they can find the specialized knowledge of their biotech partner as valuable.

 A possible downside of partnering technologically deep firms could be the fact that scientists of the client firm may have problem assimilating knowledge if it is too specialized, and there might be problems in communication and knowledge transfer between the two partners (Haeussler and Patzelt, 2008). Nevertheless, as we discussed earlier, in access alliances the primary motive of the two partners is not to acquire and learn knowledge capabilities from the other partner, but merely to access complimentary capabilities required to finalize the development of product candidates (Grant and Baden‐Fuller, 2004; Haeussler and Patzelt, 2008). Therefore, in access alliances the client firms do not face such difficulties when partnering a Gorge firm, i.e, a biotech company that is rather deep than broad in its technological resources.

Because being technologically deep is a sign of focusing limited resources on specific domains of excellence, we can expect that biotech firms with deeper technological resources would seem more appealing to a larger partner, particularly when compared to those firms with diversified but not specialized knowledge resources. Specialized knowledge from a Gorge biotech firm is particularly valued, giving the firm more bargaining power when negotiating a partnership. Therefore, a Gorge type of biotech firm has more chances of forming desirable downstream alliances, when compared to a Lagoon or a Pond type of firm; all else being equal.

**Proposition 3:** *In access alliances with other firms, Gorge firms are in a better position than Lagoon firms to negotiate desirable terms.*

As we discussed, more learning and knowledge transfer take place in ‘learning’ alliances as compared to ‘access’ alliances. Empirical research on the evolution of the alliances partners’ knowledge bases suggest evidence of convergence in alliances aimed at exploring new knowledge -as a result of mutual learning; and some evidence of divergence in those alliances aimed at exploiting complementarities -as a result of specialization and knowledge access. (Gilsing and Nooteboom, 2006; Mowery, Oxley and Silverman, 1996). In a similar way, we propose that mutual learning leaves an imprint on the structuration of a biotech firm’s depth and breadth of knowledge, an effect that does not take place when simply accessing partner’s complementary assets. Access alliances’ are characterized by minimal interaction between the partners and the absence of an intensive transfer of technological knowledge (Grant and Baden-Fuller, 2004). As a result, the routines, procedures and knowledge bases of the partners remain differentiated from each other (Al-Laham, Amburgey and Baden-Fuller, 2010, Grant and Baden-Fuller, 2004).

By engaging in learning alliance firms can learn from the partner’s knowledge base and add both to the depth and breadth of their own knowledge bases. If the exploratory activity is carried out in the existing areas and knowledge domains (local search), the firm gains additional depth. If it spans into new-to-the-firm areas and knowledge domains (long-jump search), then the firm gains additional breadth of technology.

**Proposition4a:** *Engagement in learning alliances impacts the evolution of a firm’s knowledge base more than engagement in access alliances. The impact can be seen as broadening the knowledge base across and/or deepening it within knowledge domains.*

If we are to compare learning alliances with other firms to learning alliances with universities, the arguments we presented earlier about the downside of firm-firm alliances lead us to expect more transfer of knowledge as well as more exploratory activity in the learning alliances with universities. Appropriation concerns, fear of opportunistic behavior, and knowledge leakage in firm-firm alliances as well as the vast exploratory approach in university-firm projects are reasons to believe that a firm learns more intensely when it allies with universities. More intense learning, in turn, exhibits itself by deepening the firm’s knowledge base in its existing areas of expertise or by broadening it into new areas.

**Proposition 4b:** *Learning alliances with universities have a higher impact on the focal firm’s knowledge structuration than learning alliances with other firms. The impact can be seen as broadening the knowledge base across and/or deepening it within knowledge domains.*

1. **Discussion, Conclusions and Further Lines of Research**

Firms vary in the way they transform R&D inputs into outputs and build capabilities. The same amount of input may be used to broaden the knowledge base, or merely to deepen existing knowledge disciplines (Wang and Tunzelmann, 2000). Prior research suggests that in the search process underlying recombinant inventions, maintaining a balance between depth and breadth is critical to successful invention (March, 1991; Katila and Ahuja, 2002).

Managers of technology-intensive firms are faced with a strategic choice as to how broad or deep the firm’s knowledge base should be (Bierly and Chakrabarti, 1996). When a firm strengthens its competence in a certain area or practice by learning (gaining depth), the process of finding a new competence (gaining breadth) is likely to be impeded (Leonard-Barton, 1992; Van Wijk, 2003). Extensive experimentation without deep understanding of the causal relationships between technology components may prove counterproductive (George, Kotha and Zheng, 2008). On the other hand, learning processes tend to focus attention and narrow competence (Levinthal and March, 1993: 97).

Maintaining the correct balance between breadth and depth of knowledge is only possible once the firms recognizes what the implication of each dimension is for its sustainable competitive advantage. For example, a young and small firm in the exploration stage of R&D needs a different balance than a more mature firm in the development stage. Because R&D is carried out both in-house and externally, the balance in depth and breadth of knowledge also relates to a firm’s learning through alliances. Moreover, if in addition to learning and exploration, the firm engages in strategic alliances for exploiting complementarities, it should recognize how being deeper or broader in knowledge can impact the benefits it reaps from such alliance. In our paper, we take biotechnology as a research setting where firms face are the aforementioned challenges, and we offered a theoretical development to explain why and how knowledge depth and breadth both affect and are affected by the firm’s alliance activities.

Our study contributed to the literature on technology management and inter-organizational relationships by highlighting the impact of knowledge depth and breadth on alliance formations and outcomes. In light of the propositions offered in this paper, further research needs to empirically find the degree to which young and technologically deep firms are in a better position to attract desirable partnerships. Also, empirical research must evaluate to what degree our theoretical development can explain the effect of learning alliances on the firm’s depth and breadth of knowledge.

Another contribution of our paper was delineating the four strategic groups of firm based on knowledge depth and breadth. Since a particular knowledge structuration implies its unique opportunities and knowledge management requirements, further empirical research can benefit by detecting firms that fall in each group and observing systemic differences as to their knowledge management and performance. Also, longitudinal research can study the evolution and the possible moving of firms from one group to another, as they age, grow, learn and accrue technical and managerial experience as well as credibility and reputation in the marketplace.

Although our study focused on the biotechnology sector and its pertinent types of alliances, we believe that the arguments we developed here are relevant to other, science-driven high-technology industries as well, including subfields in microelectronics, advanced materials, and nanotechnology (Stuart, Ozdemir, and Ding, 2007), where dedicated technology firms engage in upstream partnerships in order to learn new knowledge while they also engage in downstream collaborations in order to exploit commercialization opportunities.

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**Table 1: Alliances as to the degree of interaction and the type of partner**

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| *Type of alliance* | *Theory* | *Partners Interaction and Knowledge Transfer* | *Examples* |
| Learning alliance with universities | Organizational Learning | High | Collaborative research agreement with universities |
| Learning alliance with other firms | Organizational Learning | Medium | Collaborative research project with another firm |
| Access alliance with universities | Knowledge access theory | Low | Licensing, marketing or distribution agreement with universities |
| Access alliance with other firms | Knowledge access theory | Low | Licensing, marketing or distribution agreement with another firm |

**Figure 1: Biotechnology firms grouped by their technological knowledge depth and breadth**

1

‘Ocean’ firms

3

‘Lagoon’
firms

4

‘Pond’ firms

2

‘Gorge’ firms

Technological Breadth

Technological Depth

High

Low

High

Low

Source: developed by the authors

**Figure 2: Hypothetical firms in each strategic group. Each point represent a patent in the given technology class. Firms B and C have the same number of patents (n=10) but the structuration is different.**



Source: Developed by the authors

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1. With a one-year lag introduced to observe results [↑](#footnote-ref-2)
2. Sources: *Recap IQ* and *Cortellis Intelligence*, Thomson Reuters 2016 [↑](#footnote-ref-3)