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HOW CAN KNOWLEDGE STRUCTURATION SERVE STRATEGIC GOALS?
A THEORY FOR TECHNOLOGY FIRMS

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Abstract

This study focuses on knowledge structuration and its strategic implications for new research-intensive firms. These firms mainly pursue growth strategies by leveraging their knowledge-based resources and capabilities in inter-organizational relationships, while they are typically constrained on other resources. Therefore, they need to strategically develop and structure their knowledge resources in a way that guarantees their survival and serves their future goals best. Taking biotechnology firms as our research setting, we first identify groups of firms with similar generic knowledge structuration, i.e. depth and breadth of knowledge possessed by the firm. Then, drawing from organizational learning theory and knowledge-based view, we discuss how strategically structuring the technological knowledge of the firm can affect the benefits it gains from collaborating with other organizations. We provide research propositions for different strategic groups and theoretically link knowledge structuration to both exploration and exploitation alliances.

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

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1. INTRODUCTION

Over the last three decades, knowledge has emerged as one of the firm's strategically most important assets (Drucker, 1993; Grant, 1996, Winter, 1987). Performance differences among firms are often a result of their different knowledge bases and differing capabilities in developing and deploying knowledge (Bierly and Chakrabarti, 1996). Innovation, which Schumpeter (1934) argues is the engine of economic development, has resulted from a novel combination of new knowledge or of existing knowledge (Grant, 1996; Henderson and Clark, 1990; Zahra, Ireland and Hitt, 2000). Similarly, an invention stems either from combining technological components in a novel manner or by reconfiguring existing components (De Boer, Van den Bosch, and Volberda, 1999). Knowledge, however, is spread among various actors, making it dispersed in time and place and differentiated in context (Doz and Santos, 1997; Hayek, 1945; Von Krogh, Ichijo and Nonaka, 2000). Therefore, the underlying knowledge structure of a firm that gives way to competitive advantage is not only made of knowledge stocks, which are accumulated knowledge assets, but also of knowledge flows, which are streams of knowledge between firms or between units of firm that may be assimilated and developed into stocks of knowledge (Dierickx and Cool, 1989; Van Wijk, 2003).

As knowledge plays a vital role in a firm's competitive behavior and survival (Grant, 2001), organization and management of knowledge have become increasingly important. Configuration of knowledge stocks and the knowledge flows between them, form a major part of a firm's knowledge strategy. If knowledge and its management are so important as determinants of firm performance, then knowledge strategies are likely to be a critical area of strategic choice for the firm (Bierly and Chakrabarti, 1996). Accordingly, in this paper we explore and delineate knowledge strategies of high-tech firms, basing our analysis in biotechnology industry. We then

theorize how these different strategies affect a firm's external learning and collaboration, and suggest research propositions for further study.

In technology-based industries, strategic alliances –collaborative arrangements involving exchange, sharing or co-development of products, technologies or services- are vehicles frequently employed by firms in order to cope with rapid technological change and ensure sustainable competitive advantage (Gulati, 1998; Hagedoorn, 1993). Although alliances are not limited to high-tech industries, past research has found that the R&D intensity or the level of technological sophistication of industries is positively correlated with the intensity and number of alliances in those sectors (Freeman, 1991; Hagedoorn, 1995). In industries such as biotechnology where there is a regime of rapid technological change, innovations and research breakthroughs are so broadly distributed that no single firm has all the internal capabilities required for success (Powell, Koput and Smith-Doerr, 1996). Sources of innovation do not reside exclusively inside firms; instead, they are commonly found in the interstices between firms, universities, research laboratories, suppliers, and customers (Powell, 1990). In the biotechnology sector, new technological knowledge is dispersed among incumbent companies (such as large pharmaceuticals), dedicated biotechnology firms, and universities/research centers (Powell, Koput, and Smith-Doerr, 1996). Our study considers entering into alliances as a possible strategic option disposed to the focal biotechnology firm, and investigates how this option relates to their knowledge strategy.

Before moving on with our discussion on how high-tech organizations, such as dedicated biotechnology firms, strategically form their knowledge bases, we need to define constructs such as technology and technology domains. Most scholars, researching innovation, consent to the broad definition that technology is knowledge of how to do things and how to accomplish human goals (Simon, 1973). Scholars have then moved forward by developing constructs to classify similar technologies to a group. Following George, Kotha and Zheng (2008) and Rosenkopf and Nerkar (2001), we define technology domain as a group of technologies that solve a primary problem. Distinguishing between similar and distant technology domains, Rosenkopf and Nerkar (2001) define technology domains as having boundaries that encompass similar innovation. A

similar innovation is a categorization of innovations to a class based on the primary problem they solve. Therefore, a technology domain is characterized by the problem it tries to solve.

Given that technology domains are somewhat discernable, a firm's base of technological knowledge can be seen as featuring two dimensions: depth and breadth. Breadth refers to the technological diversity or the scope of technology domains, while depth refers to the accumulated expertise and specialization within a single technology domain. 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). Past research has, however, paid little attention to distinguishing between breadth and depth as two exclusive dimensions of technological capabilities (Haeussler & Patzelt, 2008).

Managers of technology-intensive firms are faced with a strategic choice as to how broad or narrow the firm's knowledge base should be (Bierly & Chakrabarti, 1996). In financially-constrained biotech firms, managers need to make this decision while having in mind the firm's long-term objectives and needs which typically include cash inflow from potential alliance partners or investors as well as accessing marketing capabilities and distribution networks of large pharmaceutical firms (Lerner & Merges, 1998). They need to foresee which of the two strategies- going technologically deep or technologically broad- will help them meet their future needs by attracting better partners and more desirable partnership terms. Alliances with larger pharmaceutical firms work as sources of financial capital for the biotech firms, who lack enough resources to support their ongoing research projects and commercialize the resulting products, if any. Access to financial capital as well as distribution and marketing channels of larger firms is thus a common strategic goal among many biotech firms.

The motivation behind this study and its attempt to delineate knowledge strategy of biotechnology firms, is the existence of mixing evidence in the literature regarding the relationship between knowledge and alliance formation (Zhang and Baden-Fuller, 2010). Some

studies have found a positive effect of quantity or magnitude of a firm's knowledge base, for example the number of patents or the number of research pipelines, on alliance formation (Higgins and Rodriguez, 2006; Kinder, 2003; Quinn, 2000); while some others have found a negative effect (Harrigan, 1985; Pisano, 1990) or no effect at all (e.g. Mol, 2005).

In a study of the impact of the smaller biotech firm's resources on the amount of financial capital it receives from the larger pharma partner upon allying, Gopalakrishnan, Scillitoe and Santoro (2008) hypothesize that the extent of financial capital the biotech firm acquires is positively related to the perceived value of its technological resources. However, on the contrary to their hypothesis and to findings of other studies (e.g. Stuart, Hoang, & Hybels, 1999; Coombs, Mudambi, & Deeds, 2006) their empirical results suggest that biotech firms that entered into alliances when they had fewer technological resources (measured by number of patents) received a greater amount of financial capital from their pharmaceutical partner. They discuss that these unexpected findings point to the quality of the patents rather than the sheer number of patents that a particular firm may possess, especially when one considers that many of the bio-pharmaceutical alliances are based upon very specific therapeutic areas that pharmaceutical companies are looking to access. Perhaps what the larger pharmaceutical firms are looking for are more specific, focused technologies rather than broad-based and multiple patent technologies. It could be that the larger pharma firms have the broad-based technology platform and they enter into alliances with smaller biotech firms in order to add specific, focused technologies to their existing technological platforms (Wheelwright and Clark, 1992). If managers of a biotechnology firm are aware of such preference of their prospective alliance partners, they would decide accordingly to form their knowledge base in a way that best serves their short term goals (accessing financial capital and distribution and marketing channels of the larger firm) and long term goals (bringing about more innovations to sustain their research pipeline).

In this study we aim to investigate knowledge strategies of technology firms to find out how choosing between acquiring greater depth or breadth in knowledge results in different outcomes for the firm. We identify groups of biotechnology firms with similar knowledge strategies, i.e. firms with knowledge bases that are similar to each other in terms of their depth and breadth. Our study intends to determine how these strategies relate to the firm's collaborative activities and to

conclude by comparing how different groups differ in their performance and their strategic options.

The biotechnology industry provides a perfect setting for our study, for several reasons: First, The biotechnology industry is considered to be a highly research-intensive sector, heavily reliant on science (Meyer-Krahmer and Schmoch, 1998), and subject to radical technological innovation (Higgins and Rodriguez, 2006). It therefore offers an ideal context to analyze research activities and to develop and test theories of innovation and knowledge management (Katila and Ahuja, 2002). Second, the biotechnology industry can be divided into several technology subfields representing distinct knowledge domains that are different in their knowledge and contextual characteristics (Al-Laham and Amburgey, 2005; Folta, 1998; Pisano, 1990). Hence, we are able to observe the depth and breadth of biotechnology firms' knowledge-based resources, and monitor the variation of technological depth and breadth among firms, as these firms are often bounded by limited resources and need to strategically shape their knowledge bases, either across numerous knowledge domains or constrained to a few ones.

Another aspect of biotechnology that makes it unique and interesting to study is the prevalence of alliance activity. The sector is characterized by very high levels of alliance activity (Powell et al., 1996). The literature has found that the major motivation behind incumbent companies entering alliances with new biotechnology firms is to replenish their research pipelines (De Carolis, 2003): on average, such companies spend appropriately 14 per cent of their R&D budget externally (Myers and Baker, 2001). Although many studies have observed the impact of alliances on innovation performance in this sector (e.g. Rothaermel, 2001; Rothaermel and Deeds, 2004), and studied how and why alliances are formed (e.g. Zhang and Baden-Fuller, 2010) few studies have examined how knowledge structuration, i.e. depth and breadth, relate to alliance activity. Following Rothaermel and Deeds (2004). We identify two main types of alliances in this sector: First, 'exploration alliances' are those formed with the intention to 'acquire' and learn knowledge of the partner to discover the unknown (e.g. alliances between focal biotech firm and university/research center upstream to its activities). Second, 'exploitation alliances' are those primarily pursued with the intention to 'access' knowledge of the partner (e.g. focal biotech firm allying with large pharmaceutical firm downstream to its activities). Section 4

further discusses these two types of alliances and argues how depth and breadth of knowledge matter differently for each type of alliance.

Our study contributes to the literature on technology and innovation management by focusing on two under-investigated aspects of a technological knowledge base: depth and breadth. In doing so, we build on existing theories of the firm to delineate knowledge strategies of technology firms in relation to their collaborative activities. More precisely, we explore which type of alliance activity, as to more explorative or exploitative, relates to which dimension of a firm's knowledge base, depth or breadth. This conceptualization can help explain apparently contradicting findings in the literature regarding the role of knowledge and technological resources of high tech firms in their alliance success.

As a strategic choice, managers of technology firms need to decide whether to invest in depth or breadth of the firm's knowledge base. Our study identifies the situations in which each of the two dimensions of knowledge proves to be crucial.

The rest of this paper proceeds as the following: In section 2 we discuss the theoretical foundations of this study, which encompass knowledge-based view (KBV) of strategic alliances and organizational learning. In section 3 we identify strategic groups of firms and discuss how technology firms can strategically structure their knowledge bases. Then we relate these knowledge strategies to the type of alliance activities in biotechnology sector, building on organizational learning theory on exploration and exploitation to produce testable research propositions. Sector 4 concludes the paper and discusses further lines of research.

2. THEORETICAL BACKGROUND

2.1 Knowledge-based View of the Firm

The knowledge-based view (KBV) has grown out of resource-based theory and posits that knowledge is the primary resource underlying new value creation, firm heterogeneity and

competitive advantage (Foss, 1996; Grant, 1996; Kogut & Zander, 1992). Rather than knowledge creation, the firm's role is knowledge application: organizations serve as knowledge integrating institutions (Grant, 1996), responsible for coordination and governance of their members, who create new knowledge (Grant, 1996). The outcome of knowledge integration is organizational capability, which contributes to the performance heterogeneity of firms.

If the primary role of the firm, as the knowledge-based view (KBV) recognizes, is integrating the specialist knowledge residing in individuals into goods and services; then the primary task of management is establishing the coordination needed for this knowledge integration (Grant, 1996).

The knowledge-based view of the firm and the resource-based view share as their main objective, the exploration of a company's internal dynamics (Spender, 1996). While the resource-based view analyzes all the resources and capabilities of the organization, the knowledge-based view focuses on the role of knowledge in these organizational dynamics. According to the latter view, knowledge is the most strategically important of the firm's resources (Nonaka and Takeuchi, 1995; Grant, 1996).

More precisely, the advancement of knowledge-based view of the firm took place with contributions originating from the literature on Resources and Capabilities (Barney, 1991; Conner and Prahalad, 1996) as well as the Evolutionary Economics (Nelson and Winter, 1982), from which the KBV inherits its two main foundations. What KBV inherits from the literature on Resources and Capabilities, is viewing knowledge as the key resource from a strategic point of view (Grant and Baden-Fuller, 1995; Conner and Prahalad, 1996, Grant, 1996). Some scholars consider this new approach as the essence of the Resource-based View (RBV), as the central theme in the literature on Resources and Capabilities is that privately-owned knowledge is a basic source of competitive advantage, and the differences among firms performances are explained based on asymmetries in knowledge as well as their associated competencies and capabilities (Conner and Prahalad, 1996; Grant, 1996).

On the other hand, what KBV inherits from the literature on Evolutionary Economics is treating the firm as a social structure that has advantages over the market in terms of its ability to create

and transfer knowledge (Nelson and Winter, 1982; Kogut and Zander, 1992, 1996; Zander and Kogut, 1995). The evolutionary perspective provides the KBV with a dynamic and path dependent character, where the knowledge possessed by a company at a given time is the result of historical events or learning experiences and likewise, identifies opportunities for future learning (Nelson and Winter, 1982; Teece, Pisano and Shuen, 1997).

Drucker (1993), considers that in the new economy, knowledge is not only another resource to add to the traditional production factors (i.e. land, labour, and capital), but the main resource underlying all the firm's capabilities. In the same line with the view that knowledge has become "the" resource instead of being only "a" resource, Quin (1992) posits that the value of most products and services depends on the way in which their intangible elements are developed. These elements, such as technological know-how, product designs, client's understanding, innovation and creativity, and alike, are all based on knowledge.

2.2 Alliances and the Knowledge-based View of the Firm

Similar to the organizational learning literature, the KBV literature stresses the importance of knowledge available outside the firm (Felin & Hesterly, 2007; Grant & BadenFuller, 2004; Nickerson & Zenger, 2004). The knowledge-based view argues that the bases of knowledge and capabilities distributed heterogeneously among firms are the main determinants of their performance differences (Grant, 1996). Organizations do not only use different bases of resources and capabilities to develop knowledge, but they also have different access to externally generated knowledge (Nonaka and Takeuchi, 1995).

Over the last few years, the knowledge-based view has begun to emerge as an integrative and distinct theoretical framework to explain and understand strategic inter-organizational alliances. As in other theories of strategic alliances, the firm's ultimate objective to form strategic inter-organizational relationships in a knowledge-based approach is to enhance their competitiveness and create new value (Doz & Hamel, 1998; Gray, 2000; Gulati & Zajac, 2000). Firms are

believed to enhance their competitive position through superior management of knowledge (Grant, 1996; Kogut & Zander, 1992; Nonaka, 1994; Spender, 1996). Strategic alliances and collaborative relationships are seen as powerful organizational arrangements that expose organizations to knowledge they did not possess earlier (Choi & Lee, 1997; Grant & Baden-Fuller, 2004). Organizations gain competitive advantage through strategic alliances by effective management of knowledge across organizational boundaries (Coakes, Bradburn, & Sugden, 2004; Ding & Peters, 2000; Grant & Baden-Fuller, 1995).

According to the Knowledge-based View of the firm, there are three basic alternatives for transferring and integrating knowledge: internalization within the firm, market contracts, and collaboration contracts including strategic alliances and business networks. External learning (Kogut & Zander, 1992) can be fostered through alliances (Grant & Baden-Fuller, 2004). According to KBV, inter-organizational collaboration can be seen as a means to create, transfer and integrate knowledge, providing the firm with access to such new knowledge that it cannot or does not want to develop internally. Therefore, it can be viewed as a means for the firm to improve its competitive position by exploiting new opportunities for innovation (Grant and Baden-Fuller, 1995). As attested by Grant and Baden-Fuller (2004) "A knowledge-based theory of the firm is used to identify circumstances in which collaboration between firms is superior to either market or hierarchical governance in efficiently utilizing and integrating specialized knowledge". But, what are those circumstances?

The answer to the above question can be derived by considering three aspects of knowledge integration and transfer: First, knowledge characteristics; second, the efficiency of utilizing knowledge-based resources of the firm; and third; the uncertainty and dynamism regarding knowledge applicability (Kogut and Zander, 1992; Grant and Baden-Fuller, 1995). These three aspects lead to four actual situations where collaboration agreements (such as alliances) offer advantages over both firms and markets, as to knowledge transfer and integration (Grant, 1996):

The first situation deals with explicit knowledge, which, codified by definition, can be easily transferred through market contracts. In this way, the inefficiency of the market in transferring such knowledge is associated to its failure in effectively governing such transactions in the face

of appropriability problems. In this situation, collaboration agreements are a way to avoid such problems as they allow repeated exchange of knowledge in a reciprocal fashion. In fact, in knowledge-intensive industries, such inter-organizational agreements play an important role in transferring and integrating explicit knowledge (Grant and Baden-Fuller, 1995).

The second situation relates to the efficiency in utilizing firm's knowledge. When the firm's product domain perfectly matches with its knowledge domain, highest level of efficiency in utilizing knowledge is obtained. However, the range of knowledge required for a given product is typically very wide, and most of this knowledge is not product-specific. Few firms are therefore able to achieve a full match between the domains of their knowledge and their products. That is to say, the firm, by itself, might not be efficiently using some of its knowledge; or, it might produce products for which it doesn't possess the whole range of required knowledge. In the first case, the firm can increase the efficiency of knowledge utilization by selling or giving away the under-utilized knowledge. In the second case, the firm can benefit from obtaining its knowledge requirements externally for a given product which, if developed internally, would be under-utilized. Therefore, the greater the mismatch between product domains and knowledge domains of the firm, the more are the advantages offered by inter-organizational collaborations (Grand and Baden-Fuller, 1995).

Finally, in addition to the absence of a match, there are two more aspects related to knowledge-product links that justify the use of collaboration agreements: Uncertainty and dynamism (Kogut and Zander, 1992). Rapid technological change creates uncertainty over future knowledge requirements of a product. Given that knowledge acquisition and integration is a time-consuming process, firms need to invest in knowledge which has uncertain returns. In such a situation, collaboration with another organization can help the firm minimize its investment commitments. The higher the uncertainty, the higher the benefits derived from inter-organizational collaboration, as opposed to internalization, as a means to integrate knowledge (Grand and Baden-Fuller, 1995).

Moreover, industries subject to rapid technological change are characterized by first-mover advantages. In such a way that firms are confronted with a dilemma formed by: the need to

rapidly access and integrate relevant knowledge, on the one hand, and the long periods of time necessary to create and integrate knowledge. In such situations, inter-organizational collaboration can offer a solution given that innovation in an industry usually implies transfer of knowledge originated in another industry. Collaboration agreements with firms in the source industry can significantly reduce the time required for accessing and integrating the knowledge in question (Mowery et. al. 1996).

We will further discuss these collaborations in section 2.3. For now, we stay focused on firm level and we will discuss different knowledge strategies and choices that firms must make on their own, before reaching an alliance.

2.3 Knowledge Strategies: Exploration or Exploitation?

Previous research has found that firms focus their exploration activities on technological domains that are closely related (Rosenkopf and Nerkar, 2001). By such constant focus on similar technologies, firms innovate incrementally and become experts in their current domains. When it leads to competitive advantage, this accumulated expertise is considered a distinctive competence. However, researchers have well established that this focus on similar or closely related technological domains can lead firms to develop 'core rigidities', as inappropriate or inadequate sets of knowledge, which are the flip side of core capabilities (Leonard-Barton, 1995). Other researchers have described the same phenomenon as falling into 'competency traps' (Levitt and March, 1988). Firms fall into competency traps by failing to conduct enough explorative activities and excessively focusing on exploitative tasks which ensures only short term profits and accomplishment of goals. Also, competency traps can occur when favorable performance in the near term with an inferior procedure leads an organization to accumulate more experience with it, thus keeping its experience with a superior procedure in an insufficient level for it to be rewarding to use (Levit and March, 1988).

On the other hand, constant exploration for new knowledge and new opportunities is a highly uncertain and unpredictable activity. It reflects the ability of a firm to acquire new knowledge rather than merely learning how to use current knowledge more efficiently to meet economic ends. It generates new, unsettled knowledge with potentially high but uncertain and unpredictable returns (Liu, 2006). Therefore, scholars have increasingly indicated the need for firms to achieve a balance between their exploration and exploitation activities (e.g. Brown & Eisenhardt, 1998; March, 1991; Levinthal & March, 1993; Gavetti and Levinthal, 2000), as 'excessive dominance by one or the other will be dysfunctional' (Cohen and Levinthal, 1990).

Since the publication of March's (1991) seminal article, a multitude of theoretical and empirical research works have investigated exploration and exploitation; refined, extended and tested its theoretical aspects and contributed to the literature on knowledge, technology and strategic management (e.g., Benner and Tushman, 2003; Gupta, Smith, and Shalley, 2006; Katila and Ahuja, 2002; Powell, Koput, and Smith-Doerr, 1996; Sigglekow & Levinthal, 2003). However, in addition to finding the proper balance between exploration and exploitation, many knowledge-based firms need to make another strategic choice, which is far less investigated in the literature: Finding the proper balance between depth and breadth of their knowledge base (Henderson and Cockburn, 1994, Hamel and Prahalad, 1994, Hedlund, 1994). Breadth refers to the technological diversity or the scope of activities, while depth refers to technological focus and the accumulated expertise in a single technology domain. Exploration or basic research can thus add to both depth and breadth of a firm's knowledge base, depending on whether it contributes the knowledge domains the firm already has expertise in, or it expands the firm's knowledge into new areas. Exploitation, on the other hand, is the practice of applying knowledge, whether it is deep or broad, in order to create value. It is therefore a consequence, rather than an antecedent, of depth and breadth of knowledge.

3. KNOWLEDGE STRUCTURATION AND STRATEGIC ALLIANCES

3.1 Knowledge Strategies: Depth or Breadth?

Organizational knowledge base has been differentiated and examined along a variety of dimensions (Yayavaram and Ahuja, 2008). The size of an organization's knowledge base is related to its innovative productivity (Fleming, 2001; Ahuja and Katila, 2001). The degree of similarity or overlap between different organizational knowledge bases (knowledge relatedness) has also been associated to an organization's ability to absorb external knowledge from its geographical or technological neighbors (Mowery, Oxley and Silverman, 1996; Lane and Lubatkin, 1998). Despite the numerous studies examining these dimensions of an organization's knowledge base, knowledge structuration, or the structure of a firm's knowledge portfolio across (breadth) and within (depth) technology domains, has received far less attention (George, Kotha and Zheng, 2008). Research has found that the range of disciplines relevant to firms' innovative processes is expanding in both breadth, i.e., the number of relevant disciplines, and depth, i.e., their sophistication and specialization (Wang and von Tunzelmann, 2000).

Depth of a technological knowledge base can be defined as its accumulated level of expertise within a technological territory (George, Kotha and Zheng, 2008). Firms possessing deep knowledge are in a better position to understand casual linkages of the old components within the territory and also to make new combinations from old components (March, 1991). 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).

Breadth of a technological knowledge base refers to the scope of activities and diversity of technologies encapsulated in product-related or process-related form (Wang and von Tunzelmann, 2000) and it is defined as the range of technological knowledge areas in which the firm has expertise. Since a firm with a broad knowledge base is familiar with many territories on the technological knowledge landscape, it is capable of exploring more paths and into new regions (Kauffman, Lobo and Macready, 2000). As with deep knowledge, studies have also

found that firms with "broad" knowledge seek to improve their positions with further search (Brusoni, Prencipe and Pavitt, 2001; Zhang and Baden-Fuller, 2010)

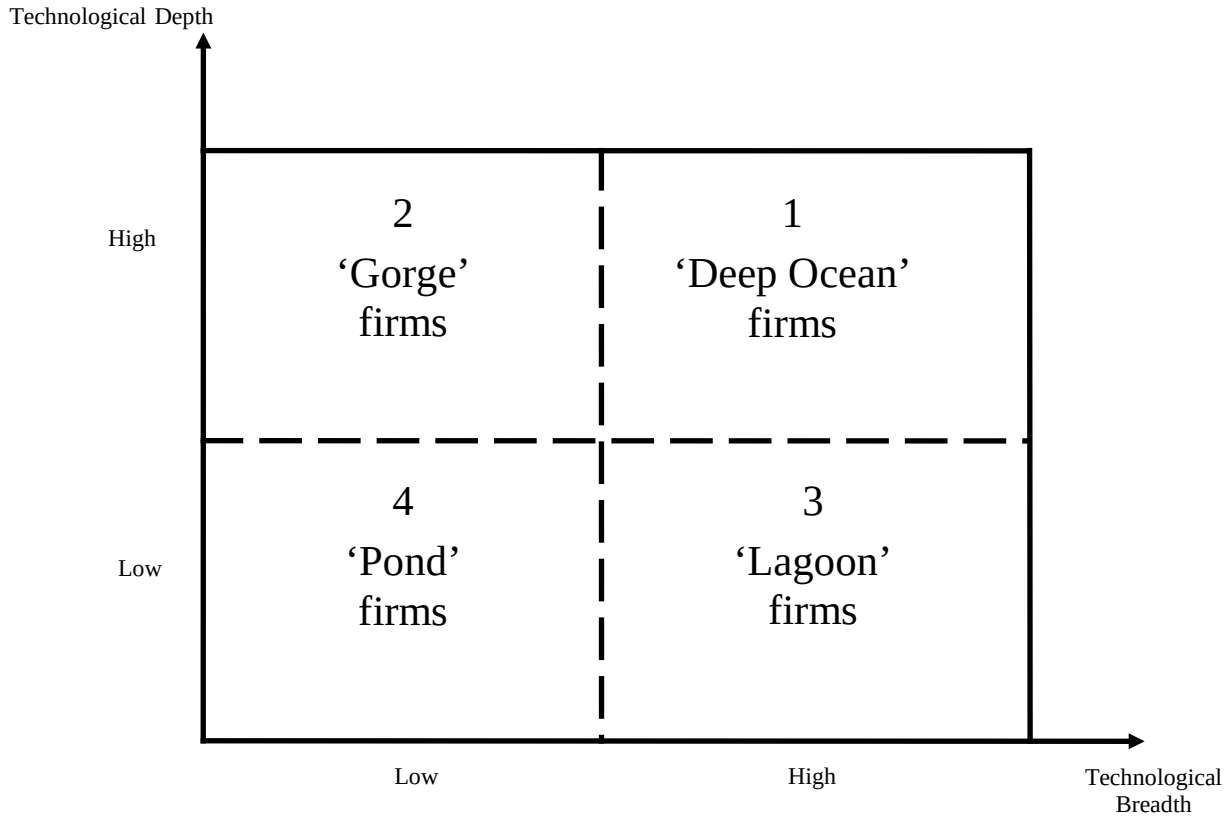
The question of how the firm should structure its knowledge base is especially salient in biotechnology industry, where many start-ups and young firms, resource-constrained by definition, need to enter into those new technological niches or domains that are expected to generate payoffs in the future. As discussed earlier, many pharmaceutical firms ally with biotechnology firms to perform discovery and development activities and ensure that their drug pipelines are not too narrow or lacking promising products. But besides biotech-pharma partnerships, another type of alliance is often formed between a biotech firm and a research center or university upstream to its activities, usually to identify, learn and further contribute to scientific discoveries generated in universities, which can later lead to prototypes and products in the market. In fact, during the last decade, most of the drugs on the market with biotechnological origins had their roots in technologies acquired by licensing agreements for scientific discoveries made in universities (Edwards et al., 2003). Then, one of the most significant roles performed by biotechnology firms has been to identify and in-license science created in universities, and then to further develop and ultimately transfer this intellectual property to larger firms that possess the resources to commercialize the technology (Stuart, Ozdemir, and Ding, 2007). In this vein, depending on whether the focal biotech firm allies with an upstream research center to explore new opportunities or with a downstream pharmaceutical firm to exploit complementarities, the depth and the breadth of its knowledge base serve the alliance in different ways. We'll discuss this later in section 1.3.2 after grouping the biotech firms into four possible strategic groups based on the structuration, i.e. depth and breadth, of their knowledge base.

As we said in the introduction, earlier research on the importance of technological resources in bio-pharmaceutical alliances has found that the quality, rather than the quantity and size of knowledge resources of the biotech firm relate to alliance outputs (e.g. Gopalakrishnan, Scillitoe and Santoro, 2008). Let us imagine two biotech firms: The first one has knowledge and expertise in three technology classes under the wide field of biotechnology, with a profile of 10–10–80% of its total patents granted in these classes respectively. The second firm enjoys knowledge and expertise in the same three classes, i.e. possesses the same knowledge breadth, but has a profile

of 33–33–33%. For the larger pharmaceutical firm which acts as the client of the technology developed in the smaller biotech firms, these two firms are essentially different, even if the size of their knowledge bases or the number of patents they hold, are equal (Zhang, Baden-Fuller, Mangematin, 2007), simply because the first firm is more focused in a given technology class as it has 80% of its total patents dealing with that subject matter. Similarly, two firms with patents portfolios of 80-10-10% and 80-5-5-5-5% are not equally broad in their knowledge base, even if both of them are known for possessing particularly deep knowledge in a given technology subclass (80% of their patents, even when considering the total number of patents are equal). Moreover, if the average firm in this industry has also around 80% of its patents in the first technology class, just as these two firms have, then these should not be considered 'technologically deep' firms because the depth of a firm's knowledge base is to be evaluated when comparing it relative to other firms in the industry.

Based on the above, and 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 (see figure 1 below): 1) 'Deep 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, when compared to other firms. 2) 'Gorge' firms: those that possess a deep but not broad knowledge base, in comparison to other firms in the marketplace. 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, when compared to their competitors. They are thus similar to a lagoon which is known primarily for being wide and broad rather than deep. 4) Finally, 'Pond' firms are those firms which are nor deep neither broad in their technological resources. The following figure illustrates the four groups across dimensions of depth and breadth:

Figure 1.: Biotechnology firms grouped according to the depth and breadth of their technological knowledge



Biotechnology firms in each of the above mentioned groups face different challenges and requirements for managing their knowledge bases, and they also encounter different opportunities, especially when it comes to inter-firm collaborations and alliances. As mentioned before, these partnerships are very common phenomena in biotechnology, so much that we can consider them as part of a firm's strategic goals. Zhang and Baden-Fuller (2010) showed that the quality of firm's knowledge base, as measured by depth and breadth, has sophisticated influences on technology collaboration.

We expect that 'Pond' biotech firms end up in an alliance with larger incumbent firms (such as pharmaceuticals) only if they give up too much control and ownership of the technology in alliance or accept unfavorable terms. As they are neither deep nor broad in their technological

knowledge, we expect that these must be younger firms still moving towards broadening and/or deepening their technological resources, therefore, many in-licensing alliances with universities are also expected here.

Proposition 1: *In average, Pond firms are younger than firms in the other three strategic groups*

Proposition 2: *Pond firms engage in more upstream exploration alliances (e.g. with universities and research centers) relative to firms in the other three strategic groups.*

On the opposite side, we expect that 'Deep Ocean' firms are such resource-rich biotech firms that they rarely need alliances with larger pharma firms. They are probably large enough to have managed developing such broad and deep knowledge bases, and they might have access to other sources of financing such as venture capitalists. As to alliance with universities, we expect that these large (and older) firms engage in less university alliances as they mature (Roathermel and Deeds, 2004).

Proposition 3: *In average, Deep Ocean firms are larger than firms in the other three strategic groups*

Proposition 4: *Deep Ocean firms engage in less upstream exploration alliances (e.g. with universities and research centers) relative to firms in the other three strategic groups*

At this point, the two remaining groups, 'Gorge' and 'Lagoon', are where our study needs to dig in more and discover how their deep and broad knowledge bases, respectively, relate to their alliance activity. The following section discusses how the breadth of knowledge comes into play in exploration alliances (e.g. focal biotechnology firm allying with upstream university partner), where the depth of knowledge plays a role in exploitation alliances (e.g. focal biotech firm allying with downstream pharma partner).

3.2 Knowledge Structuration and Inter-organizational Collaborations

As we said in the introduction, the knowledge-based literature has identified two distinct types of activities for the management of knowledge: Exploration or knowledge generation, and exploitation or knowledge application (March 1991, Spender 1992). Exploration refers to those activities that increase an organization's stock of knowledge, while exploitation refers to those activities that deploy existing knowledge to create value.

By engaging in exploration, firms can add both to the depth and the breadth of their knowledge bases. Rosenkopf and Nerkar (2001) identify four different types of exploration behavior: Local exploration that spans no boundary; external exploration that spans only organizational boundaries but not technological boundaries; internal exploration that spans only technological boundaries but not organizational boundaries; and finally, radical exploration that spans both boundaries. The first two types add to the depth dimension of a firm's knowledge base by conducting explorative and basic research in existing knowledge domains; while the last two types add to a firm's breadth of knowledge base as they span technological boundaries and include new technology domains. Previous research has, however, found that firms focus their exploration activities on technological domains that are closely related (Rosenkopf and Nerkar, 2001). Exploitation activities, on the other hand, do not significantly contribute to the depth or breadth of a firm's knowledge base, as they include only applying existing knowledge in order to create value.

In the case of strategic alliances, the distinction between exploration or knowledge generation and exploitation or knowledge application relates to a key distinction in the ways in which the alliance partners share knowledge among themselves (Grant & Baden-Fuller, 2004). Knowledge generation addresses alliances as means of *learning* in which each partner uses the alliance to acquire and absorb the partner's knowledge base. Knowledge application addresses a form of knowledge sharing in alliances where each partner *accesses* its partner's stock of knowledge in order to exploit complementarities, but with the intention of keeping its distinctive knowledge base. While confirming that learning happens in all alliances and that some alliances are pursued primarily by the intention to acquire partner's knowledge, Grant and Baden-Fuller (2004) argue

that knowledge accessing rather than knowledge acquisition is the primary motivation for knowledge-based alliances. In the same line, Rothaermel and Deeds (2004) find that biotechnology firms enter into significantly more exploitation alliances than exploration alliances. Koza and Lewin's theoretical work (1998) also assumes that an industry will as a rule be characterized by more exploitation alliances than exploration alliances.

A firm's choice of the type of alliances to enter can be distinguished by its motivation to either exploit an existing opportunity or explore for new ones (Koza and Lewin, 1998). Interestingly, the biotechnology sector encompasses alliances with both types of knowledge-sharing: There exists alliances where learning and knowledge-acquisition, rather than knowledge-access, is the main motivation. For example, in many alliances formed between biotechnology firms and research centers or universities (upstream to the focal firm), the firms need to absorb and learn its partner's knowledge. These are what Rothaermel and Deeds (2004) call "exploration alliances"; where the biotechnology firm's motivation is to acquire basic knowledge that can be used to create novel molecular entities which are later entered into development and regulatory process. On the other hand, the industry is also scene to thousands of alliances where knowledge-access, rather than knowledge acquisition, is the main motivation for allying. These are usually alliances between biotechnology firms and more established firms (e.g. pharmaceuticals) downstream to their activities. Rothaermel and Deeds (2004) call these "exploitation alliances", as they are formed with the intention to exploit complementarity capabilities. Scholars suggest that many firms use interfirm collaborations to gain access to, rather than to acquire, other firm's capabilities; supporting more focused, intensive exploitation of existing capabilities within each firm (Grant and Baden-Fuller, 1995; Mowery, Oxley and Silverman, 1996). As we said earlier, the biotechnology firm gains access to the established firm's legal and regulatory competence, manufacturing, marketing and distribution channels as well as financial capital. The established firm, on the other hand, 'accesses' the new technology developed in the biotechnology firm and the specialized knowledge embodied in it, not with the intention to learn, but merely to be able to commercialize the technology and appropriate future profits.

Following Rothaermel and Deeds (2004), we consider two main types of alliance where the focal biotechnology firm might engage in - Upstream (exploration) alliances and downstream

(exploitation)alliances. In discussing how depth and breadth of the focal firm's knowledge base relate to its collaborative activities, we need to notice that the firm takes different roles in each type of alliance.

3.2.1 Knowledge Structuration and Exploration Alliances

In an exploration alliance, typically with universities and research centers, the focal biotech firm serves as the 'receiving end' of the transfer of knowledge and technology, and thus its absorptive capacity plays a crucial role on how effective the knowledge is transferred and how much the firms benefits from the alliance. 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). Investment in breadth, rather than depth 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). Therefore, biotech firms that invest in broad knowledge are in a better position to learn from their upstream alliance partners. However, investing in broad knowledge is not all what it takes for a biotech firm to benefit from its upstream, exploration alliances. Although investments in the breadth of knowledge determine the extent to which knowledge will be overlapping or not with a potential learning partner, investments in deep knowledge are required too, in order to increase learning performance and to allow a firm to learn about more complex matters (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998; Van Wijk, 2003). Deep knowledge gains from specialization and specialization fosters rationalization and routinization (Cohen and Levinthal, 1990; Leonard-Barton, 1995). Therefore, depth of knowledge base may increase the efficiency and decrease the cost of absorbing knowledge (Henderson and Cockburn, 1996; Van den Bosch, Volberda and Deboer, 1999; Van Wijk, 2003). Altogether, it results that both depth and breadth of knowledge base are crucial for a biotechnology firm to learn and benefit from its upstream (exploration) alliance.

Proposition 5: *Both Lagoon and Gorge firms outperform Pond firms in acquiring partner's knowledge in an upstream (exploration) alliance*

3.2.2 Knowledge Structuration and Exploitation Alliances

In exploitation alliances, however, biotech firms are no longer in the receiving end of supply of technology and knowledge, but in the 'giving end'. They provide technology for their typically larger and more established partners, such as pharmaceuticals. The pharma partners, however, often seek "access" to a specific technology, drug target or group of potential drugs (Dunne, Gopalakrishnan, Scillitoe, 2009). By investing in deep knowledge the biotech firm signals its pharma partner that it has focused its limited resources on few technological areas. If those technologies offer promising future as to commercialization possibilities, we can expect that biotech firms with deeper technological resources would seem more appealing to a potential pharma partner. By focusing its limited resources on excelling in few technology domains, a Gorge type of biotech firm has more chances of achieving such promising technologies and therefore attracting desirable downstream alliances, when compared to a Lagoon type of firm; all other things being equal. Exploitation partnerships imply more knowledge access rather than acquisition on the receiving end, hence the breadth dimension of the receiving end -pharmaceutical firm's- knowledge base does not play as much a crucial role as it plays in exploration alliances, neither does the breadth dimension of the giving end, the biotech firm.

Proposition 6: *A Gorge firm is more likely to attract desirable partners in a downstream (exploitation) alliance (e.g. with established pharmaceutical firm) than a Lagoon or Pond firm.*

4. DISCUSSION, CONCLUSIONS AND FUTURE LINES OF RESEARCH

In the 21st century, knowledge management is the core competency for many companies, and how to learn in a fast, safe, and effective way is a critical question for firms especially in the face

of rapid technological change. This study shows that the *quality* of firm's knowledge base, as measured by depth and breadth, has sophisticated influences on technology collaboration. The dimensions of depth and breadth discussed in this paper pose specific organization design requirements if knowledge is to be effectively developed and exploited. Managers of new biotech firms face these requirements when adopting their strategy for developing knowledge and expertise that can further lead to patents granted to the firm. Patents are a sign of their firm's success and accomplishment (Coombs et al. 2006), helping them in attracting financial capital from venture capitalists and/or alliance partners.

By relating to exploration and exploitation, our analysis on the role of depth and breadth of knowledge also points to the firm's short and long-term performance. Learning processes tend to focus attention and narrow competence (Levinthal and March, 1993: 97). 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). However, it is variety and constant exploration for new opportunities that leads to innovation (Boisot, 1998). Cohen and Malebra (2001) found that the breadth effect of R&D activities, and the diversity it creates is one of the main causes of technological progress at the industry level.

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 test the degree to which technologically deep firms are more successful in attracting better alliance partners, and whether these dominance translates to more desirable contractual terms on control and ownership of technology, financial capital (in the form of upfront or milestone payments) obtained from the larger partner, or other measures.

Also, although our study detects four strategic groups of high-tech firms as to their depth and breadth of technological knowledge, we do not know how these firms evolve over time. Longitudinal research needs to study this 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.

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). Further research should explore and empirically test how knowledge structuration of young technology firms affects the outcomes of their collaborations as these firms act as intermediaries in alliance chains that lead to the development and commercialization of science-based discoveries originating in public sector organizations. It is yet to be discovered how differences in the two dimensions of knowledge, breadth and depth, can explain performance differences in both alliance and firm level.

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