Pablo de Olavide University
Department of Business Organization and Marketing

Doctoral Dissertation

Knowledge and Strategy in Technology Alliances

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To my parents…

“Doubt is the key to knowledge.”

Persian proverb

Knowledge and Strategy in Technology Alliances

Revealing the Roles of Depth and Breadth of Knowledge

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Mohammad Saleh Farazi

Chapter 1

Introduction

Chapter 1: Introduction

1.0 Abstract

In this introduction chapter I aim to present the main concepts and phenomena that are studied throughout the dissertation. I will also explain how the layout of the dissertation is organized and how the research questions and findings of the three pieces of research relate to each other. After a brief review of "what we already know" about technology alliances, I address some gaps in the relevant literature to further discuss "what is still to be known" in order to present the motivation behind this study. I will also elaborate on the expected contributions that I hope this dissertation will make to the literature.

1.1. Introducing Technology Alliances

As the title of the dissertation -"Knowledge and Strategy in Technology Alliances"- suggests, this work draws on the intersection of two main disciplines of management: knowledge management and strategic management, and then it further applies the theories developed in these two disciplines to study technology alliances as an increasingly important phenomenon in today's business world.

Generally speaking, strategic alliances are collaborative arrangements between two or more organizations in order to pursue a set of agreed upon objectives while remaining independent entities. Firms enter strategic alliances because they recognize the value-creation potential of pooling together their resources and capabilities. Because alliances are prevalent in many industries, and because they inherently challenge the view of organizations as discretelybounded entities, researchers have made extensive efforts to understand the antecedent conditions that lead to inter-organizational collaboration (Stuart, 1998).

High-technology industries deal with production of goods and services which require cutting-edge technologies. As opposed to other industries, high-tech sectors are often synonymous with complexity, shorter product life-cycles, rapidly changing environments and technological conditions, and hence, more demand for rapid strategic decision-making. As we said, alliances are prevalent in many industries; but particularly in high-technology industries, they appear to have become a routine strategic initiative. This is primarily due to the complexity of products and services offered - no single firm has all the internal capabilities required for success- and also because of the inherent uncertainty associated with technology development and innovation in such volatile, rapidly changing environments. Alliances in high-tech sectors can take on different forms, ranging from technology-licensing agreements, to collaborative R&D partnerships or equity joint ventures (Powell, Koput and Smith-Doerr, 1996).

Under the pressures of a rapidly changing environment and the inherent difficulty to predict future changes, managers of high-technology firms are faced with several challenges: they need to strategically develop their internal knowledge-based resources, match those resources with the best possible partnerships with other organizations, while maintaining a balance between short-term and long-term needs and necessities of the firm for achieving a sustainable competitive advantage (Barney, 1991). Recognizing the challenges that high-tech firms are facing under the pressure of competition and uncertainty, this dissertation digs into the knowledge-based resources of technology firms, studies how they are developed and how they can be configured, in order to further discuss how firms can strategically leverage different dimension of their knowledge-based resources.

1.2. Choosing Biotechnology as the Research Setting for the Dissertation

Biotechnology is the use of living systems and organisms to develop products addressing real-world needs and applications. The United Nation's Convention on Biological Diversity (CBD), defines biotechnology as "any technological application that uses biological systems, living organisms or derivatives thereof, to make or modify products or processes for specific use"[1].

As a high-tech industry, biotechnology is scene to many alliances that join the coordinated efforts of three types of organizations: universities, dedicated biotechnology firms, and established life sciences companies (Arora and Gambardella, 1990). These alliances take place in various forms: From the point of view of the dedicated biotechnology firm and its position in the value chain, an alliance can be vertical and upstream (with universities and research centers), vertical and downstream (with established life sciences companies such as large pharmaceuticals) or horizontal (with other biotechnology firms working at the same level of value chain but possessing complementary assets, for example). As a highly research-intensive sector[2], the biotechnology industry heavily relies on science (Meyer-Krahmer and Schmoch, 1998) and it is also subject to radical technological innovation (Higgins and Rodriguez, 2006). Therefore, biotechnology is an ideal research setting for this dissertation as it provides a context to observe and investigate knowledge and innovation in inter-organizational strategic collaborations.

[1] UN Convention on Biological Diversity, Article 2. Text available at: www.cbd.int/convention/text/

[2] According to a 2015 report by Thomson Reuters, bio-pharmaceutical industry ranks as the second most innovative industry, when patent filing is considered. Source: http://stateofinnovation.thomsonreuters.com/

1.3. Gaps in the Literature

The growing interest in how organizations learn from their partners, access their partner's knowledge, and develop new competencies through alliances has led to the emergence of a distinct stream of research. This stream explores how knowledge is managed in different types of alliances (Inkpen, 1998), how knowledge sharing among partners takes place (Mowery, Oxley and Silverman, 1996; Tsai, 2002), and know knowledge about collaboration per se develops over time and impacts collaborative outcome (Doz, 1996; Phelps, Heidl and Wadhwa, 2012; Powell, Koput and Smith-Deorr, 1996; Simonin, 1997).

Moreover, there is another large body of research which studies the relationship between knowledge and alliance formation or performance. This stream can itself be divided into three major groups: The first group emphasizes the effects of quantity or magnitude of a firm's knowledge base, for instance the number of research pipelines (Higgins and Rodriguez, 2006) or the number of patents (Shan, Walker and Kogut; 1994) on alliance behavior and performance. While some studies found a positive effect (e.g. Kinder, 2003; Quinn, 2000), some found a negative one (Gopalakrishnan, Scillitoe and Santoro; 2008; Harrigan, 1985; Pisano, 1990), and some did not find a constant effect at all (e.g. Mol, 2005). The second group of research has focused on the types of knowledge to be transferred or created through the learning process that takes place during the alliance, such as tacit versus explicit knowledge (Dhanaraj et al., 2004; Inkpen and Wang, 2006; Nielsen and Nielsen, 2009), embedded knowledge (Tsang, 2000), and ambiguous knowledge (Simonin, 1999). These studies have been insightful in describing the learning process, but they do not explain why a firm allies with other organizations and how knowledge can affect choice of partner. Finally, the third group has studied the question of who allies with whom by examining the relationships of knowledge features between alliance partners. They have focused on similarity of firms' technological knowledge (e.g. Rothaermel and Boeker, 2008) However, as asserted by George, Kotha and Zheng (2008) and re-confirmed by Zhang and Baden-Fuller (2010) "thus far few studies explicitly account for a firm's knowledge *structuration* within organizational boundaries" (George et al., 2008, p. 1451) in alliance formation research. In other words, the literature has paid little attention to the features of a firm's knowledge base, for example it's depth and focus as compared to its breadth and diversity, and the effect that these features might have on the firm's propensity to form alliances, its success to get favorable partnership terms and its ability to be innovative in alliance. This dissertation, therefore, takes a step forward to address this gap in the literature by focusing on how a firm's technological and knowledge resources can be structured in different ways, what strategic implications each type of structuration has, and how they relate to alliance-level and firm-level outcomes.

1.4. Research Questions and Dissertation Layout

The three chapters immediately following this chapter, each deal with aspects of knowledge structuration and how it plays a role in different types of alliances (e.g. alliances upstream versus downstream to the focal technology firm). In chapter 2 we take the first step by identifying strategic groups of biotechnology firms according to the way they structure their knowledge-bases; and then we ask and try to answer the question: "How does these strategies relate to the firm's collaborative activities with other organizations?" We distinguish between different types of alliances and suggest research propositions that pave the way for the next two chapters. Chapters 3 and 4 are therefore empirical investigations of the theoretical discussion developed in Chapter 2.

In chapter 3, we address the following question: “How can biotech firms leverage their knowledge resources to retain control in alliance with pharma partners considerably larger than them? How do depth and breadth of the technological resources of the biotech firm affect the alliance governance structure?”

Finally, in chapter 4, we shift our attention to alliances between the focal biotech firm and universities, and we address the following research question: “How does the focal firm’s orientation towards allying with universities, as opposed to allying with other firms, combines with its knowledge structuration to affect overall innovative outputs from collaborations?”

Figure 1.1 shows the layout of the dissertation. Outputs of Chapter 2 serve as inputs for Chapters 3 and 4. Chapter 5 reviews all the findings and concludes this dissertation by discussing the contributions and implications for theory and practice.

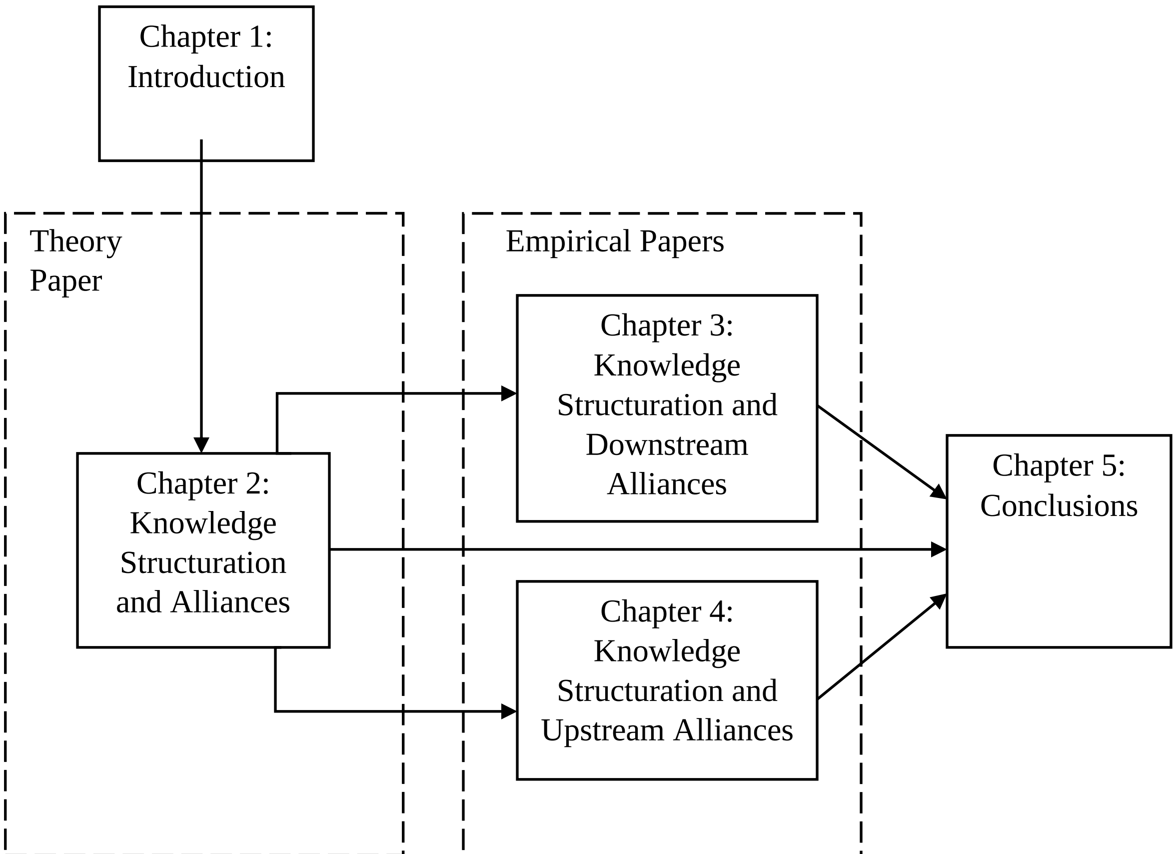

Figure 1.1 The Layout of the Dissertation

1.5. Expected Contributions

The primary idea for writing this dissertation was formed after encountering contradicting findings in the literature regarding biotech-pharma alliances and the impact of the biotechnology firm's technological resources on the amount of financial capital it acquires from the larger pharma partner. Research findings were inconsistent as some showed a negative impact, some found a positive impact, and some did not find any impact at all, as we mentioned above in section 1.3. The primary contribution that we expect this set of research to make to the literature on technology management, is therefore to suggest a way to explain these contradicting findings by offering an alternative way to look at technological resources of the ‘knowledge-source’ firm in alliance. In other words, our research is expected to make a set of contributions all revolving around the idea of knowledge structuration in technology alliances. As we will see in the next three chapters, these contributions are not limited to explaining past findings, but also include highlighting the importance of paying attention to such knowledge structuration both for researchers and practitioners. Researchers can investigate many types of associations between knowledge structuration and firm and alliance-level variables in different settings, while managers find theoretically developed and empirically proven support for the idea that “it is not only the quantity and magnitude of technological resources that matter”. What matters more for alliance and firm success, is how the managers structure those resources and how they further exploit them in combination with other resources and capabilities.

Chapter 2

Technology Firms, Knowledge Strategies and Alliances

Chapter 2: Technology Firms, Knowledge Strategies and Alliances

2.0. Abstract

The purpose of this chapter is to identify groups of high-technology firms with similar generic knowledge strategies, and determine how these strategies relate to the firms' collaborative activities. Taking the biotechnology sector as our research setting, we draw from organizational learning theory and knowledge-based approaches to alliances to discuss how the depth and breadth of technological knowledge relate to a high-tech firm's alliance activity. We suggest propositions for further research, linking depth and breadth of knowledge to both exploration and exploitation alliances.

2.1 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). Based on this statements, 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 chapter 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.

This chapter proceeds as the following: In section 2.2 we discuss the theoretical foundations of this study, which encompass knowledge-based view (KBV) of strategic alliances and organizational learning. In section 2.3 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 2.4 concludes the paper and discusses further lines of research.

2.2. Theoretical Background

2.2.1. 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.

2.2.2. 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.

2.2.3. 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.

2.3. Knowledge Structuration and Strategic Alliances

2.3.1. 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 2.1 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:

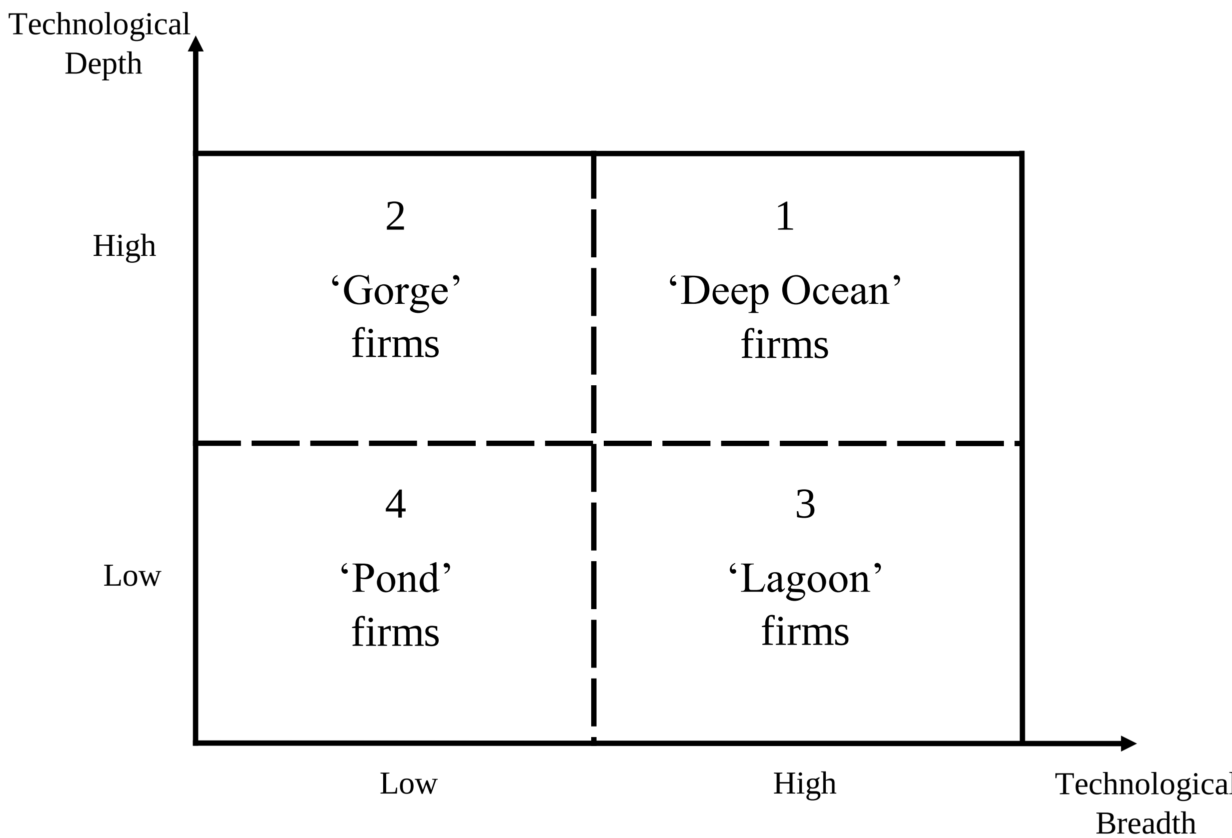

Figure 2.1.: Biotechnology firms grouped according to the depth and breadth of their technological knowledge

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).

2.3.2. 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.

2.3.2.1 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*

2.3.2.2 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.*

2.4. 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.

Chapter 3

High-technology Firms in Vertical Downstream Alliances:

The Impact of Technological Depth and Breadth on

Alliance Governance Structure

Chapter 3: High-technology Firms in Vertical Downstream Alliances: The Impact of Technological Depth and Breadth on Alliance Governance Structure

3.0 Abstract

New high-tech firms have extensively used strategic alliances with large incumbent partners to access complimentary resources and capabilities and to finance their technology projects. However, due to their initially weak bargaining position, they tend to relinquish a disproportional amount of control rights to the large financier of the R&D alliance. This raises the question: How can new biotech firms leverage their knowledge resources to retain control in alliance with larger pharma partners? And, does alliance experience add to their leverage? Focusing on equity and non-equity types of alliance governance, we examine how the firm's depth and breadth of technological knowledge resources impact the choice of governance structure. Our findings suggest that technology firms with deeper technological resources are better able to retain control when allying with the larger firm. The relationship is stronger when the new firm has more alliance experience.

3.1. Introduction

In the recent past, organizations have substantially increased their use of alliances (Das & Teng, 2000; Kale & Singh, 2007; Zaheer, Gulati, & Nohria, 2000). Strategic alliances include a wide range of collaborative arrangements between two or more firms, which are aimed at improving their competitive position and performance (Hitt, Dacin, Levitas, Arregle & Borza, 2000; Ireland, Hitt & Vaidyanath, 2002). As important tools for accessing resources, learning and thus sustaining competitive advantage, alliances have been viewed as ubiquitous phenomena in management research literature (Hagedoorn, 2002), and studies suggest that, on average, alliances do create economic value (Chan et al., 1997; Anand and Khanna, 2000).

Researchers have found that the level of technological sophistication of industries or the R&D intensity is positively related with the number of alliances (Hagedoorn, 1995). In addition to rationales such as pooling complementary assets and risk sharing, a number of scholars have described the use of alliances by firms to acquire technology-based capabilities from alliance partners (e.g., Kogut, 1988; Hamel, Doz, & Prahalad, 1989; Cohen & Levinthal, 1990; Hamel, 1991). Researchers have also shown that alliances can contribute to the performance of high technology firms, and there is agreement that the structure and knowledge flows within alliances can affect a firm's innovativeness and performance (e.g. Arora & Gambardella, 1994; Deeds & Hill, 1996).

High technology, especially science-based industries such as biotechnology have seen tremendous growth in the number of strategic alliances in the past two decades (Powell, 1998, Hoang & Rothaermel 2010). A frequent phenomenon is the formation of alliance between large, established firms (such as pharmaceuticals) and smaller new entrants (such as biotechnology firms); providing an opportunity where the downstream expertise of the large firms can be utilized by the smaller partners, who can excel in upstream activities such as product innovation or new product development (Rothaermel & Boeker, 2008). Many biotechnology firms rely on strategic alliances with large pharma firms to bring in resources that they lack, such as financial capital (Coombs and Deeds, 2000), and downstream capabilities (Rothaermel and Deeds, 2004), and also to improve their market valuation (Janney and Folta, 2003). Biotechnology firms typically specialize in a particular area of scientific or technical expertise and leverage this expertise when partnering with larger pharmaceuticals, usually in an attempt to receive higher amounts of financial capital or give away less managerial control when negotiating the alliance setup and governance (Rebentisch and Ferretti, 1995; Gopalakrishnan, Scillitoe, & Santoro, 2008).

Although in need for resources from the pharmaceutical firm, the biotechnology firm may desire to keep full control and authority over the alliance technology in order to appropriate more of the resulting profit stream when this technology is fully developed and commercialized. This desire to retaining control in the alliance governance means that the biotechnology firm is reluctant to allow the pharma partner to purchase any of its equity (Dunne, Gopalakrishnan and Scillitoe, 2009).

Broadly speaking, alliance governance involves choosing between equity and non-equity forms, also referred to as quasi-hierarchies and quasi-markets, respectively (Gulati, 1995; Narula and Hagedoorn, 1999; Osborn and Baughn, 1990; Pisano, 1989). Prior research has described differences in alliance governance structures as being similar to the differences between markets and hierarchies (Gulati, 1998). Non-equity alliances are similar to market transactions with less contractual complexity, as they include contractual arrangements without equity exchange. Equity relationships, on the other hand, are similar to more hierarchical forms of governance, as they include joint ventures and minority equity alliances (Gulati, 1998).

Past research has found that, due to their initially weak bargaining position, new technology ventures tend to relinquish a disproportional amount of control rights to the financier of the R&D alliance (Aghion and Tirole, 1994; Lerner and Merges, 1998). As predicted by Aghion and Tirole (1994) and empirically supported by Lerner and Merges (1998) and Lerner et al. (2003), financially constrained firms tend to give up too much ownership of the innovation when entering an alliance. Dessein (2005) finds that early stage projects, where there exists lots of information asymmetry among partners, are where the most rights are given up. However, despite being smaller, biotech firms possessing valuable knowledge resources can still have bargaining power in alliance negotiations with larger pharma partners. It is known that larger pharmaceuticals ally with smaller biotech firms in order to access those technological resources that they lack or can't cost-efficiently build internally (Audretsch & Feldman, 2003). These technological resources that are crucial to the formation of the alliance, may also be the main source of competitive advantage for the smaller biotechnology firm. That's how the biotechnology firm's resource contribution to the alliance, i.e. its technological capabilities, can also serve as its key source of leverage when allying with a resource-rich pharmaceutical company (Dunne, Gopalakrishnan, & Scillitoe, 2009). The importance of knowledge and technological resources in science-based firms such as biotechnology firms is so much that many scholars have described them as being driven by scientific discoveries and innovative performance and not only by regular profit-seeking (Oliver and Liebeskind, 1997).

Biotech firms vary considerably in terms of their technical capital and stage of technology, and this impacts how the biotech partner exerts its influence in the alliance. If the biotech firms possess valuable R&D capabilities as indicated by the scientific quality of their technological resources, they are less likely to be forced by the alliance partner to give up equity rights (Bosse & Alvarez, 2010). Past research also indicates that new technology firms use their scientific resources to bargain for additional financial capital from their partners at the time of forming vertical technology alliances (Deeds, Decarolis & Coombs, 1997). Scholars have also found that the characteristics of knowledge involved in the alliance relationship have the highest impact on choice of governance structure (e.g. Carayannopoulos & Auster, 2010, Oxley and Sampson, 2004).

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, 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, as a possible explanation, that pharma firms are looking for more specific, focused technologies rather than more broad-based, multiple patent, platform technologies. However, little empirical research has been carried out to examine whether technologically-specialized or technologically-diversified firms differ in their ability to leverage their technology resources and exert their influence when allying with a larger firm.

In the previous chapter we studied knowledge strategies of small technology firms and discussed how the depth and the breadth of their technological knowledge relate to their alliance activity. In this chapter, we focus on the focal biotechnology firms and the alliances that they form with established, typically larger pharmaceutical firms, which operate downstream to their activities. As an output of chapter 2, we found that there must be a link between knowledge structuration (i.e. depth and breadth) in the biotech firm and its success in attracting desirable downstream partnerships. In this chapter we further dig into the dynamics of such a relationship, build on previous research and empirically test the extent to which knowledge structuration affects the degree of control the biotech firm manages to retain in downstream alliances.

The empirical study in this chapter therefore builds on the theoretical development of chapter 2 which brought into the forefront two under-researched dimensions of technological resources, namely ‘breadth’ and ‘depth’. Past recent has rarely distinguished between breadth and depth as exclusive dimensions of technological capabilities (Haeussler & Patzelt, 2008). As we said earlier, by breadth we refer to the technological diversity or the scope of technological activities, while by depth we refer to the accumulated expertise in a single technology area.

Firms need to find the proper balance between the depth and breadth of their knowledge bases (Hedlund, 1994; Henderson & Cockburn, 1994). In technology-intensive firms managers are faced with a strategic choice as to how broad or focused the firm’s knowledge base should be (Bierly & Chakrabarti, 1996). Managers of financially-constrained biotech firms need to make this decision while having in mind both the firm’s short-term and long-term objectives and needs: Cash inflow from potential alliance partners or investors and accessing distribution networks of large pharmaceutical firms on the one hand, and carrying out research needed for bringing about further innovations on the other hand (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 having more leverage in their partnerships.

Developing technological resources and investing in their depth or breadth of knowledge, is a complex, time-consuming process. Some of the development of knowledge happens through rational investment and decision-making, whilst others happen by chance. Biotech firms can learn from their previous alliance experience by investing on the dimension that gives them more leverage in future arrangements. As they build up more alliance experience and get to know expectations of potential partners, they can also learn how to effectively leverage their resources and negotiate for better alliance terms. Therefore, in this study we also take into account the biotech firm's prior alliance experience. Biotechnology firms which have had a greater number of alliances within a network have a social embeddedness which signals their reliability and credibility (Gulati, 1995). Past research has found that biotech firms may choose to leverage their credibility by retaining a full ownership position through formation of non-equity alliances (Dunne, Gopalakrishnan and Scillitoe, 2009). However, our study departs from past work by examining the impact on alliance governance structure of a combined factor: technological depth and breadth of the technology firm combined with its prior alliance experience.

The aim of this study is to analyze the two different challenges that biotech firms are faced with. The managers of the biotech firms need to decide on going for "deeper" or "broader" knowledge base when strategically planning their scientific activities. Upon forming an alliance with a larger pharma firm, the managers of the biotech firm might also be faced with the choice of giving up equity or ownership control in order to gain access to needed resources; or the challenge of how to leverage their own resources to go for less involvement in the form of a non-equity arrangement. This leads to the research question that we address: How can new biotech firms leverage their knowledge resources to retain control in alliance with larger pharma partners? How do depth and breadth of the technological resources of the biotech firm affect the alliance governance structure?

Our study contributes to the literature on strategy and technology management by examining how the strategic choice regarding depth and breadth of a technology firm's knowledge base relates to the outcome of its alliance governance negotiations. In a study of generic knowledge strategic in the US pharmaceutical industry, Bierly and Chakrabarti (1996) found that pharma firms with broader (and shallower) knowledge base were less profitable. We believe our study can bring similar strategy implications and contribute to the literature on technology management by finding which technology firms, as to their breadth or depth of technological resources, were more successful in maintaining control in their alliances. We also bring insights on how prior alliance experience affects how the biotech firm leverages its technological resources in its subsequent partnerships.

Most recent research on co-development alliances argues that a biotechnology firm (upstream partner) and pharma firm (downstream partner) often have different objectives or goals with different challenges (Fang, Lee & Yang, 2015). It is commonly believed that in most biotech-pharma alliances, the big pharma partner chooses among many potential biotech partners (Mason & Drakeman, 2014). Nevertheless, there is also evidence that biotech firms often have alternative options as well, therefore both of the partners must be willing to partner with each other (Diestre and Rajagopalan, 2012). Biotechnology firms with partners significantly larger than themselves can still have bargaining power to get their interests met when the two parties have opposing governance interests (Bosse & Alvarez, 2010). Therefore, although the objectives and insights of both partners are important, in this study we focus on the biotech firm's resources and its perspective of alliance governance as it often has sufficient influence and decision-making power in the negotiation process.

The rest of this chapter proceeds as follows: In section 3.2, we present the theoretical background that led us to develop our hypotheses relating depth and breadth of biotech firm's technological resources to the type of governance in their alliance with large pharma partners. In section 3.3 we discuss the research methods so that in sections 3.4 we can empirically test the hypotheses and present the results. Section 3.5 concludes this chapter by discussing the findings, as well as the limitations of this study and future lines of research.

3.2 Theoretical Background & Hypotheses Development

3.2.1 A Brief Overview of the Evolution of Theoretical Perspectives on Alliances: Transaction Cost Economics and Resource-based View

The Transaction Cost Economics (TCE) and Resource-based View (RBV) and are two of the most frequently used theoretical approaches for investigating choice of governance. A central theory in the field of strategy, the Transaction Cost Economics (Williamson, 1979; 1989) addresses questions about why firms exist in the first place (i.e., to minimize transaction costs), how firms define their boundaries, and how they must govern operations. This theory emphasizes transaction cost efficiency as the motivation for forming strategic alliances. The starting point in this tradition is the individual transaction (the synapse between the buyer and the seller). The question then becomes: Why are some transactions performed within firms rather than in the market. The choice of governance in an alliance, as we discussed earlier, can also be said to be closer to that of a firm (quasi-hierarchy, for example, when one or more partners take an equity stake in the other partner), or of a market (quasi-market, without any exchange or sell of equity among partners). Drawing from Transaction Cost Economics, numerous studies in the strategy and organization theory have focused on 'partner uncertainty' as the primary determinant of governance choice in alliances (e.g. Pisano et. al, 1988; Gulati, 1995; Oxley, 1997; Das and Teng, 1998). This literature suggests that difference alliance governance forms offer different degrees of control over the uncertainty surrounding partner cooperation, and that trust is a social mechanism for cooperation that allows a departure from or a reduce in the complexity of bureaucratic or contractual mechanisms of control (Das and Teng, 1998). By adopting this view, some scholars suggest that as alliance partners accrue more trust throughout their interaction history, they reduce the need for control, therefore leading to a systematic evolution of alliance relationships from the safeguards and contractual complexity of hierarchically-controlled arrangements towards the trust-based flexibility of less hieratically-governed relationships (Gulati, 1995, Casciaro, 2003).

To put it in a nutshell, studies within TCE show that factors such as uncertainty, the risk of opportunism, and information asymmetries influence the selection of governance mechanisms (Hennart and Reddy, 1997; Vanhaverbeke et al., 2002). Although offering many valuable insights, meta-analyses of TCE studies show inconsistent results with respect to the relationship between TCE factors and governance choice (David and Han, 2004). The logic of transaction cost minimization fails to capture many of the strategic advantages of alliances such as learning, creation of legitimacy, and fast market entry (Eisenhardt and Schoonhoven, 1996). Moreover, TCE has also been criticized for ignoring the impact of individual firm differences and firm capabilities on governance decisions, and for not recognizing that organizational boundaries may exist in the absence of opportunism (Conner and Prahalad, 1996). Scholars therefore suggest that one strategy to tackle these deficiencies is to bridge TCE with a theory of knowledge (Brouthers and Hennart, 2007; Conner and Prahalad, 1996; Zhao et al., 2004).

The other theoretical approach used frequently in exploring the choice of governance is, as we said, the Resource-based View, in which firms are seen as bundles of resources (e.g. Wernerfelt, 1984; Peteraf, 1993). By resources we refer to strengths or assets of the firm that may be tangible (e.g. financial assets, technology) or intangible (e.g. managerial skills, credibility and reputation). Studies in the RBV tradition extend this view to alliances by arguing that strategic alliances occur when firms in vulnerable strategic positions need that resources brought by alliances or when firms in strong social positions exploit their assets to create alliance opportunities. Therefore, alliances are seen as being driven by a logic of strategic resource needs and social resource opportunities (Eisenhardt and Schoonhoven, 1996; Eisenhardt and Martin, 2000). In comparison with TCE, the RBV perspective emphasizes: First, strategic and social factors, not transaction costs; second, characteristics of the firm (e.g. strategy, top management), not the transaction; and third, a theoretical logic of needs and opportunities, not efficiency (Eisenhardt and Schoonhoven, 1996).

The RBV therefore views alliances as mechanisms for exploiting existing firm-specific assets. However, critics suggest that RBV reaches a boundary condition in high-velocity environments because it emphasizes exploitation of current competencies rather than the acquisition of new knowledge (Eisenhardt and Martin, 2000). Again, many researchers suggest that employing the Knowledge-based View (KBV) as a theoretical frame for examining the boundaries of the firm can be helpful as it generates new and valuable insights (Brouthers and Hennart, 2007; Zhao et al., 2004). In particular, KBV extends our understanding of firm boundaries as it explicitly recognizes knowledge as a critical resource. The KBV approach extends and compliments TCE, because it brings a new dimension of efficiency – knowledge-transfer efficiency (Kogut and Zander, 1993). In addition, KBV extends RBV because it examines both the exploitation of existing firm resources and the firm's ability to develop new capabilities and access knowledge beyond firm boundaries (Grant and Baden-Fuller, 2004). With this added focus on knowledge variables and organizational choices in dynamically competitive environments, KBV offers a deeper understanding of governance choices. In the next section we discuss in details how technology alliances are viewed from a KBV lens.

3.2.2 A Knowledge-based View of Technology Alliances

Departing from the RBV, the Knowledge-based View (KBV) of the firm posits that sustained competitive advantage of a knowledge-based firm is due to existence of knowledge resources which are rare, valuable, and non-imitable (Grant, 1996). Focusing on technological resources of the biotech partner, this study adopts a KBV lens in studying how these firms strategically use their technology resources to reap most benefit from their alliances with downstream pharma partners.

According to the knowledge-based view, inter-organizational collaborations can be seen as a mean to create, transfer, and integrate knowledge, providing the firm with access to such new knowledge which it can't or does not want to develop internally. Therefore, alliance can be viewed as a means for the firm to improve its competitive position by exploiting new opportunities for innovation (Grant & Baden-Fuller, 1995). In the same way that the knowledge-based view has stemmed from the theory of resource-based view of the firms, "knowledge-based explanations of the formation of strategic alliances have their roots in resource-based approaches to alliances" (Grant & Baden-Fuller, 2004). The large number of alliances in R&D intensive sectors points to technological resources as playing a major role in the formation of alliances (Hagedoorn, 1993).

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). The first type refers to those activities that increase an organization’s stock of knowledge, while the second one refers to those activities that deploy existing knowledge to create value. In the case of strategic alliances, this distinction between knowledge generation and 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. Their work provides the perfect theoretical foundation for our research setting, where the primary intention of the pharmaceutical firm is to access (rather than acquire) the biotech firm’s knowledge.

A stream of alliance research literature has paid particular attention to internal sources of capabilities that foster knowledge dissemination and integration (e.g. Henderson and Clark, 1990; King and Zeithalm, 2001; Heimeriks, 2007). This stream pays attention to the role of experience in intra-firm capability development, and explains concepts that enable firms to leverage the alliance performance. In these studies, it is suggested that the level of firm’s alliance capability and its prior experience are accountable for the persistent heterogeneity in performance differences among firms (Heimeriks, 2007).

Another stream of research has studied the risk of opportunism in alliances and its association with alliance governance (e.g. Gulati, 1995; Gulati and Singh, 1998; Sampson, 2004). Because partner firm behavior is unobservable and costs of opportunism are high, firms entering into alliances face considerable moral hazard problems. “These problems are particularly pronounced in R&D alliances where valuable knowledge and technology may be exposed’’ (Sampson, 2004: 485). Involving complex knowledge or innovative resources, many alliances between biotechnology and pharmaceutical firms face increased risks of knowledge leakage, where the smaller partner may not be able to both accomplish their role in the alliance and block the partner from taking advantage of their resources (Dunne, Gopalakrishnan, & Scillitoe, 2009). More hierarchical governance structures, such as equity alliances, are formed to mitigate opportunism and appropriability problems associated with the alliance (Gulati & Singh, 1998; Balakrishnan & Koza, 1993)

As attested by Grant (1996) “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”. Applying this notion to the governance type inside an alliance, our study adopts a KBV approach when examining whether quasi-market or quasi-hierarchy governance structure is preferred for managing an inter-firm collaboration.

3.2.3 Hypotheses Development

As mentioned earlier, the objective of this study addresses the gap in the literature by investigating the effect of technological depth and breadth of a new technology firm on its ability and propensity to maintain equity rights in the alliance with a larger firm. In our setting, we believe that biotech firms use their technological resources to bargain for giving away less control to their pharma partner, and that those biotech firms with many previous alliances leverage their resources more effectively than those without. Biotechnology firms might prefer to retain equity ownership in their company because that means retaining more of future revenue streams, retaining control of the organization and protecting their technological knowledge. On the other hand, they might be willing to sell equity in exchange for acquiring greater financial capital from their alliance partner as well as accessing their downstream capabilities or expertise (Dunne, Gopalakrishnan, & Scillitoe, 2009).

Past research has found mixed results regarding the benefits that technological resources bring to the biotech firm when allying larger pharma partner. Gopalakrishnan, Scillitoe and Santoro (2008) found that biotech firms who 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. This is contrary to their hypotheses and to findings of of other studies (e.g. Stuart, Hoang, & Hybels, 1999; Coombs, Mudambi, & Deeds, 2006). They discuss, as a possible explanation, that pharma firms could be looking for more specific, focused technologies rather than more broad-based, multiple patent, platform technologies. In order to empirically test whether more focused technology firms are preferred over more broad-base ones, we categorize tech-based firms into four groups, as each firm's stock of knowledge can be both broad and deep, only broad, only deep, or neither broad nor deep.

As we also saw in Chapter 2, figure 3.1 divides biotech firms into four groups based on their knowledge strategy emphasis: 1) 'Deep Ocean' firms are 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 possess a knowledge base which is deep but not broad, 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, 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 broad rather than deep. 4) Finally, ‘Pond’ firms are those biotech firms which are nor deep neither broad in their technological resources.

We expect that ‘Pond’ firms can enter into alliances with larger pharma firms only if they give up control and ownership of the technology in alliance. On the other hand, 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, or they would probably obtain financing from venture capitalists and other sources. It follows that the two remaining groups, ‘Gorge’ and ‘Lagoon’, are where the focus of our study is. We would expect to see more alliance activity in these two groups and we seek to find out if these two groups differ in the way their alliances with larger pharma firms are governed. We formulate our hypotheses considering all types of firms, however we would like to investigate how technological breadth and depth exclusively affect the firm’s success in maintaining equity rights over their technology when allying with a larger firm. We later discuss different findings in each of the four groups.

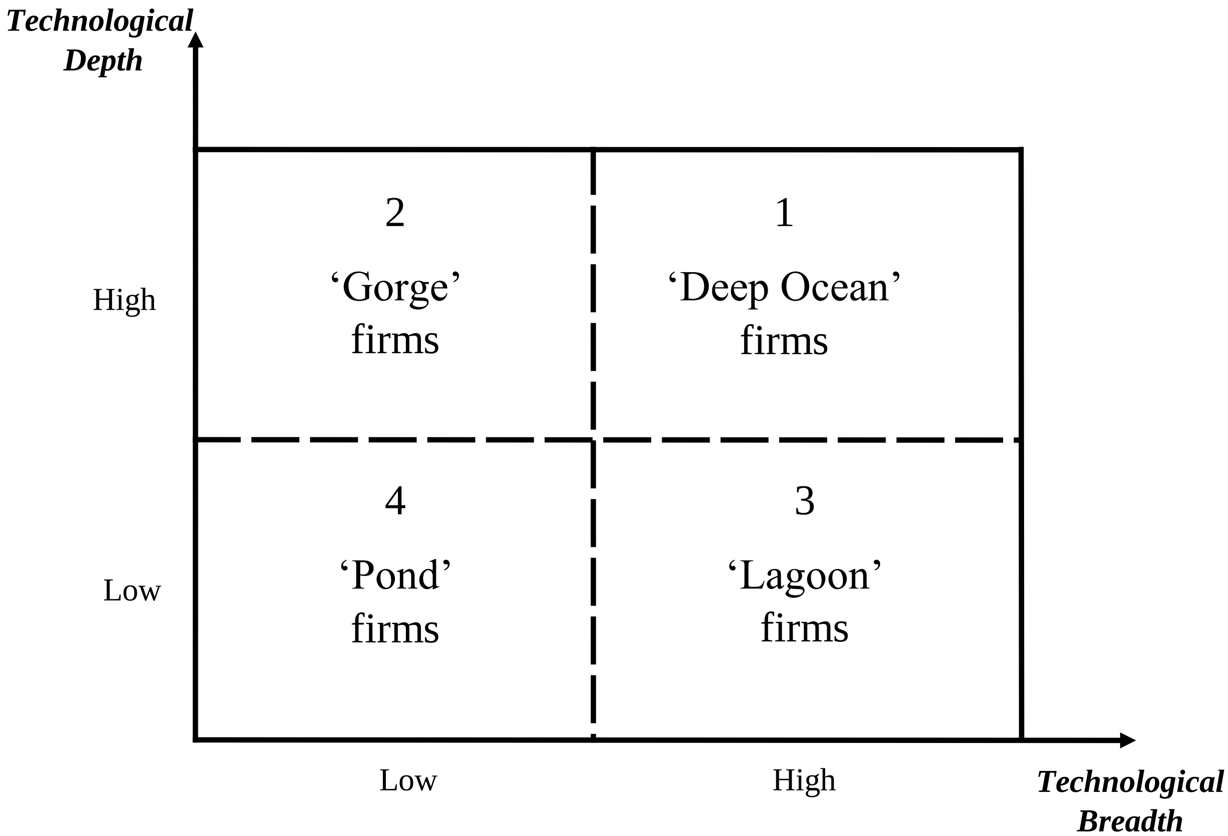

Figure 3.1.: Biotech firms divided into four groups depending on depth and breadth of their technological resources

3.2.3.1 Technological Depth and Alliance Governance Structure

Small firms typically prefer less hierarchical governance modes from fear of losing their autonomy, while, based on RBV, large firms prefer more hierarchical alliances to have the exploitation power over the resources but also the final outcome of the collaborative process (Pateli, 2009). Although in need for resources from the pharmaceutical partner, the smaller biotechnology firm might still want to keep its ownership and thus resist on giving away equity shares to the pharma partner, in order to appropriate more possible profits from its under-developed technology if and once successfully commercialized. Empirical research has found that quasi-market alliances, are preferred by firms that expect the future value of the alliance to be high, and face high endogenous uncertainty as a result of a competitive relationship with the partner (Pateli, 2009).

With limited resources, it is usually best to focus on specific domains of knowledge (core competencies) so that you can become leaders in those areas (Bierly & Chakrabarti, 1996). Hamel and Prahalad (1994) demonstrated the strategic importance of developing core products and a deep knowledge base in few critical areas. Many of the biopharma alliances are based on very specific therapeutic areas and the pharma partner often seeks access to a specific technology, drug target or group of potential drugs (Dunne, Gopalakrishnan, Scillotoe, 2009). We can therefore expect that biotech firms with deeper technological resources would seem more appealing to a potential pharma partner. By being technologically deep the biotech firm signals its pharma partner that it has focused its limited resources on few technological areas.

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 (Haussler & Paetzelt, 2008). However, as we mentioned earlier, we expect that in our setting the primary motive to enter into alliance is not to acquire knowledge capabilities from the partner, but to access complimentary capabilities required to finalize the development of product candidates (Haussler & Paetzelt, 2008). Therefore pharma firms do not face such difficulties when partnering Gorge firms, i.e, firms that are rather deep than broad in their technological resources.

Established pharmaceutical firms typically have a broad knowledge base and are not specialized on a particular set of technology and products (Zhang, Baden Fuller, & Mangematin, 2007). This can lead them to find the specialized knowledge of their biotech partner as valuable. That is to say, the expected future value of a technology under development in a Gorge biotech firm can be perceived as high (Pateli, 2009), since accumulated expertise implies that the biotech firm has focused its limited resources on excelling in one or few particular areas. Specialized knowledge from a Gorge biotech firm is particularly sought after, giving the firm more bargaining power and ability to exploit its leverage to give away less control to the pharma partner. This leads to hypothesis 1:

Hypothesis 1: The deeper the technological resources of the biotech firm, the less likely it is to give up equity to the larger pharma partner when forming an alliance.

3.2.3.2 Technological Breadth and Alliance Governance Structure

In order to benefit from allying with pharma firms –which are often considerably larger and more experienced- biotech firms must counteract the risk that their partners exploit their negotiating power at the expense of the biotech firm (Haeussler, Patzelt, & Zahra, 2012). Firms with limited resources cannot simultaneously expand the depth and the scope of their knowledge (i.e., increase investment in knowledge-based resources while also increasing the diversity of the firm's technology areas). A central debate in alliance literature concerns the degree to which a firm is able to balance the need to explore and discover new knowledge resources, as opposed to the requirement to exploit established know-how (McGill & Santoro, 2009).

With a broad knowledge base, the firm is in a better position to combine related technologies in a more complex manner, and is more flexible and adaptable in response to changing environment (Bierly & Chakrabarti, 1996). Past research has found that the ability to integrate different knowledge streams and competences in a discipline is linked to higher performance (Henderson & Cockburn, 1994). The strategic alliance literature has provided empirical evidence for the value of a broad knowledge base in alliance formation. Orsenigo et al. (2001) with biotech industry data, have found that established, multi-technology, R&D-intense firms are very capable of absorbing new knowledge generated outside firm boundaries. The development of advanced biopharmaceutical products requires knowledge in several disciplines (Zhang, Baden Fuller & Mangematin, 2007). If the biotech firm has technological resources that are not broad enough, it will only be able to cover a few and initial steps of the product's value chain.

However, being technologically broad, especially in our setting of biotech-pharma alliances, has downsides too. Although with a broad knowledge base the firm can respond in a more flexible way to various technological requirements, the cost of coordination and management of knowledge in a typically small research-intensive biotech firm must not be neglected. If the biotech firm is technologically-broad, chances are higher that its potential pharma partner has expertise in one or several technology areas and is able to form an early-stage alliance, where the technology in question is not significantly advanced. Moreover, when allying a Lagoon type of biotech firm, the client (pharma) partner has a difficult time assessing the eventual market value of the new technology, as only time and continuous development in one or few areas seems to resolve such uncertainty (McGill & Santoro, 2009). Thus, the pharma partner insists on taking equity stake in the smaller biotech firm, in order to mitigate possible information asymmetry and opportunism.

The Lagoon type biotech firm, however, has less fear over opportunistic behavior from the pharma side, as opposed to a Gorge biotech firm, as the former has diversified its knowledge base over a broad range of areas and is less concerned over relinquishing control in an alliance that concerns only a few of its areas of expertise. In addition, Lagoon biotech firms are probably interested to first protect their current resources and then to acquire new competencies through learning and adding to their depth in one or few areas. They recognize that they need more cash to do subsequent research in their current areas of expertise. Therefore, they might be willing to give away equity in exchange for financial capital

A biotech firm that is technologically broad, rather than deep, signals the pharma partner that despite limited resources, it has not focused on few technology areas. That it contrary to what a pharma firm would expect from its partner, which is bringing 'depth' to complement its already broad knowledge base. The Lagoon biotech firm has thus, less leverage than the Gorge one:

> **Hypothesis 2:** The broader the technological resources of the biotech firm, the more likely it is to give up equity to the larger pharma partner when forming an alliance.

3.2.3.3 Prior Alliance Experience as a Moderator of Depth-Governance and Breadth-Governance Relationships

Alliances are often viewed (from resource-based and organizational learning perspectives) as vehicles to acquire knowledge and learn new skills and the experience gained from prior collaboration may influence subsequent strategic decisions (Nielsen, 2005). By gaining more alliance experience, firms accumulate the capability to benefit from the interdependencies across diverse collaborative behaviors (Powel, Koput, & Smith-Doerr, 1996).

Biotechnology firms that have greater alliance experience learn to better negotiate and manage alliances with diverse partners (Levitt and March, 1988). Considering that learning happens in a continuous and iterative fashion where the firm draws from previous experiences and relates them to current activities, biotech firms can use their prior alliance experience and reputation in the alliance social network (Adler and Kwon, 2002) to bargain on the contract terms with their pharmaceutical partner. Previous alliance experience also means that the biotechnology firm may have begun to institutionalize the alliance experience with a more formalized process, improving intra-organizational and inter-organizational routines and coordination (Hoang and Rothaermel, 2005).

Moreover, a biotech firm's prior alliance experience is a sign of its reliability and credibility (Gulati, 1995) and it also signals its access to other actors in the industry (Ahuja, 2000). The bargaining power of the biotechnology firm in alliance negotiations therefore increases, in accordance with its alliance experience. Biotechnology firms may opt to leverage their credibility by keeping a full ownership position through the formation of non-equity alliances (Dunne, Gopalakrishnan, & Scillitoe, 2009). Robinson and Stuart (2007) found that biotechnology firms that had past ties to influential clients in the marketplace were likely to have less contractual complexity in their subsequent alliances, as these past ties lead to greater trust between partners and fewer contractual provisions. If a firm enjoys a positive reputation as an alliance partner, then future potential partners may be more willing to trust the firm and enter into a non-equity agreement.

As we argued before reaching to hypothesis 1, Gorge biotech firms leverage the depth of their technological resources as it is a sign of accumulated expertise over time. A Gorge firm with more alliance experience, enjoys a reputation for two reasons: First, being technologically focused and well developed during time, and second, having had prior alliances which implies credibility and reliability. A Gorge biotech firm, based on the above, gains even more bargaining power as it builds up more alliance experience. This leads to hypotheses 3a:

> **Hypothesis 3a:** The negative relationship between depth of the technological resources of the biotech firm and the use of equity governance structure in alliance with pharma firms is stronger when the biotech firm has more prior alliance experience.

Prior alliance experience, even in the case of a technologically broad, rather than deep firm, implies that the firm has gained collaborative know-how, that is, the ability to develop specialized knowledge and institutionalize organizational routines as a result of previous experiences (Simonin, 1997). Generally speaking, collaborative know-how affects the ability of firms, engaged in strategic alliances, to understand and adopt proper procedures and mechanisms for knowledge accumulation, transfer, interpretation, and diffusion – and ultimately learning and innovation (Nielsen & Nielsen, 2009).

Similar to what happens to a Gorge firm when it gains more alliance experience, a Lagoon biotech firm that was initially willing to give away control in its alliances, adds to its technological resources as it acquires more alliance experience and leverages its credibility while negotiating alliance terms. This means it will depart from equity type of governance to non-equity, where it can keep more control over the technology in alliance:

Hypothesis 3b: The positive relationship between breadth of the technological resources of the biotech firm and the use of equity governance structure in alliance with pharma firms is <u>weaker</u> when the biotech firm has more prior alliance experience.

Figure 3.2 summarizes the model of our hypotheses.

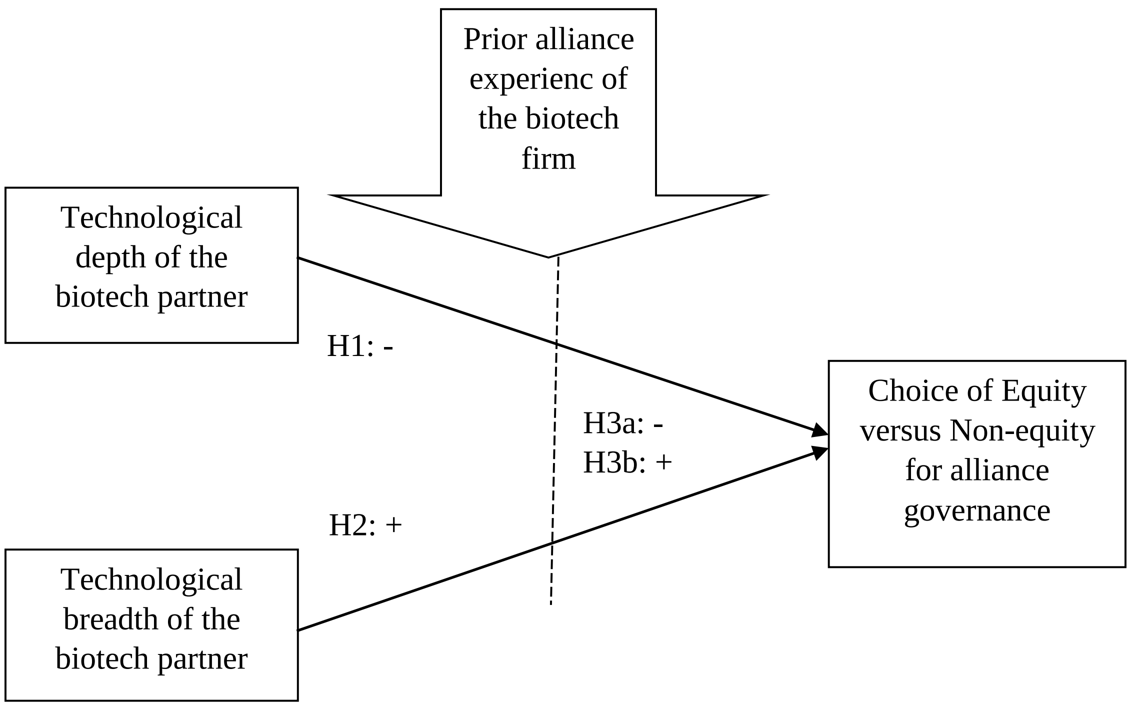

Figure 3.2: The conceptual model of the hypotheses

3.3. Research Methods

3.3.1 Research Design and Sample

To test the hypotheses of this chapter we extracted and combined secondary data from three different sources: Recombinant Capital (ReCap) for alliance data, Derwent Innovation Index for information on patents and technology classes; and Compustat for firms' financial information. Our sample comprises 390 alliances formed in the period 1995-2000 in the United States, typically by a biotechnology firm as the technology provider and a larger pharmaceutical firm as the technology client.

We constructed measures of depth and breadth of technological resources using information from the patents each biotech firm holds, as available in Derwent Innovation Index. This database provides comprehensive information on patents granted to firms in each year, and categorizes those patents based on their 'subject areas. As we are concerned with the technological resources of the biotechnology firm leading up to the alliance, we count the number of patents in a three-year period: the two years leading up to and the year of the alliance. We also record the number of those patents which fall in a given technology class or subject area. We later explain in section 3.3.2 how these numbers are used to build measures of depth and breadth.

In biopharma industry, patents play a central role in a firm's strategy as biotechnology appears to be a vital competence for innovation in drug development (Zhang, Baden-Fuller, & Mangematin, 2007). Since a patent typically includes a description of a technical problem and a solution to that problem, patent data provide a consistent chronology of firms' knowledge accumulation (Shan, Walker, & Kogut, 1994).

For alliance-level information, we used the ReCap database (Recombinant Capital), which tracks the alliances of US and non-US based firms in the biotechnology and pharmaceutical industries. This database consists of published company information submitted and reviewed by the Securities and Exchange Commission. Finally, we used Compustat database to extract all relevant firm-level financial data of the partnering firms, such as their total assets and profitability in the years leading up to the alliance formation.

We selected the years 1995-2000 for two reasons: At the end of the year 2000, US federal funding increased significantly for biotech research, and hence, biotech firms had greater opportunities to gain funds from the government starting from 2001. However before this date, they were more reliant on financial capital from other industrial firms (Industry Studies, 2000). With respect to data prior to the year 1995, alliance specific data for biotech firms within the ReCap database were not available for alliances formed prior to 1995.

3.3.2 Measures

Dependent Variable: Alliance governance structure $Gov(E, NE)$ is the dependent variable of our study. We categorized all alliances in our sample as non-equity (NE coded as 0) or equity (E coded as 1) alliances (Gulati and Singh, 1998). There were a total of 296 non-equity alliances and 94 equity alliances in the study sample.

It is important to clarify that, although equity-based relationships include both minority equity and joint venture agreements, but we exclude the latter form of partnership from our study. This is because joint ventures create a new organizational entity in a mutual hostage arrangement that implies unique governance dynamics regarding the longevity of the relationship and intertwining of resources (Bierly and Coombs, 2004). In other words, the motivation behind entering a joint venture agreement and factors influencing a firm's decision in this regard are substantially different than those shaping a firm's choice of minority equity relationships as opposed to non-equity agreements. We therefor focus on two broad categories of alliance structures: equity, excluding joint ventures, and non-equity.

Independent Variables: Technology depth ($DEPTH$) and technology breadth ($BREADTH$) are our independent variables, both calculated at the alliance level. This means that, if a single biotech firm entered to several alliances in different years from the 1995-2000 window, values of depth and breadth are calculated separately for each alliance, as the number of patents granted to a firm and subsequently, it's technological depth and breadth, can vary through years.

Following Zhang, Baden-Fuller and Mangematin (2007), we measure depth or *concentration of knowledge base* in two steps. First, the "Revealed Technological Advantage" (RTA) of each firm is computed:

$$\mathrm{RTA}_{it} = \frac{P_{it}/\sum_t P_{it}}{\sum_i P_{it}/\sum_{it} P_{it}}$$

Where P is the number of patents held by firm *i* in technology class *t*. The above ratio is the ratio of the share of firm *i* patents in technology class *t*, to the share of all patents falling in that technology class. Then, we calculate the coefficient of variation for all the firm's RTA measures, as it follows:

$$\mathrm{depth} = \frac{\sigma\mathrm{RTA}}{\mu\mathrm{RTA}}$$

The RTA accounts for concentration of a firm in a given technology class relative to all firms in the industry. As we said earlier in section 3.2.2 while defining the four strategic groups of firms, a firm is called technologically-deep when it possesses specialized and concentrated expertise in one or few technology classes “when compared to other firms in the marketplace”. Employing RTA as illustrated above, we obtain this “relative” measure. The ‘depth’ equation above indicates that a firm’s technological depth is high when it has developed a high relative technological advantage in one or few technology classes, whereas a vector of equal RTA values would result in a relatively low measure of depth (Zhang and Baden-Fuller, 2010)

The technology class *t* in the RTA formula as illustrated above is what Derwent Innovation Index labels as ‘subject area’ for each given patent in the database. It is possible that a single patent falls in more than one subject areas, for example in both “Chemistry” and “General & Internal Medicine”. With the help of Derwent Innovation Index, we identified a total of 123 technology classes where firms in our sample had patenting activity in, during the three-year period prior to entering their respective alliances. Our calculated measure of depth yielded an average of 6.6 for each alliance, where the alliance with the “technologically-deepest” biotech partner in it had a depth value of 12.08 and the alliance with the “technologically-shallowest” firm in it had a depth value of 2.27.

Technology breadth is the range of knowledge areas that the technology firm has expertise in. For measuring it, we simply count the total number of technology classes in which the firm was granted patents in the 3 years leading up to the alliance (Zhang, Baden-Fuller and Mangematin; 2007). From the total of 123 technology classes that were identified, the technologically-broadest biotech firm obtained a breadth value of 48, while the technologically-narrowest firm obviously got a breadth value equal to 1.

Prior Alliance Experience $(ALLYEXP)$: Our moderating variable is biotech firm's prior alliance experience. This is measured as the total number of alliances with all alliance partners that the biotech firm had prior to and including the formation of the alliance with the pharmaceutical firm in question. The total number of prior alliances is coded as an integer ranging from 1 to 24, and the mean number of prior alliances with other firms was 5.35.

Control Variables: While investigating the factors that affect choice of governance, we take into account and control for other variables that can have an impact apart from technological depth and breadth.

Entry Stage of Technology Development $(STAGE)$: Past research suggests biotech firms struggling for financial resources have no choice but to enter alliances in the early stages, while as a result of having less bargaining power they may give up more control rights to the pharma partner (Aghion and Tirole, 1994). Similarly, the bargaining power of the new firm increases with the development stage of the product candidate (Aghion and Tirole, 1994). Therefore, an important control variable in our study is the stage of development of the technology in the alliance. Entry Stage of Technology Development is the development stage of the technology associated with the alliance upon formation. Following Gopalakrishnan, Scillitoe and Santoro (2008) we identify four main stages: Discovery (coded as 1), Early Clinical (coded as 2), Late Clinical (coded as 3), and Launch (coded as 4).

Relative Size of Agreement $(AGREEMENTSIZE)$: When evaluating the possibilities to ally with larger pharma firms, a biotech firm might have to choose between receiving more financial capital through the alliance in exchange for relinquishing some control by giving up equity ownership; or keeping its full control in the form of a non-equity alliance but getting less financial capital. Past research has found that the likelihood of the larger partner receiving equity in its smaller alliance partner increases as the financial capital offered to the smaller partner becomes greater (Bosse and Alvarez, 2010). Hence, the financial capital offered by the larger pharma partner, also called the size of the initial agreement, is an important factor influencing the alliance governance structure. However, an amount that seems a large incentive for a small firm might not be as appealing to a larger biotech firm. We therefore accounted for the "size of the agreement relative to size of the biotech firm" and operationalized this variable as the ratio of "total up-front payments" (the dollar value of funds provided by the partnering pharmaceutical firm to the biotech firm at time of alliance formation) divided by "the biotech firm's size" (See below).

The biotech firm's size ($SIZE$): Following Coombs and Deeds (2000), we control for the firm's size, measured by the total assets of the biotech firm at the time of alliance formation. The average dollar value of total assets for each biotech firm was collected from the Compustat database for the year prior to the alliance and the year of the alliance. Due to skewness and the large variability in this measure, a log transformation was used.

The biotech firm's age (AGE): We also controlled for firm's age, which is the number of years elapsed since the founding of the biotechnology firm.

3.4 Analysis and Results

Figure 3.3 shows the scatterplot of the alliances in our sample, based on the calculated values of technological depth and breadth associated to the biotech partner in the given alliance. From the total of 390 alliances, we first removed 11 observations with outlier 'breadth' values. We then split the remaining set of values for depth and breadth into groups of higher or lower than the average, to plot Figure 3.3. In fact, this figure corresponds to our earlier grouping of firms into 4 categories, namely: 1) Deep Ocean, 2) Gorge, 3) Lagoon, and 4) Pond firms[3].

It is interesting to note that our earlier expectations hold: First, firms which are both broad and deep are not likely to need alliances. In a total of 390 alliances, we observe only 13 alliances comprising "Deep Ocean" biotech firms. Most "Deep Ocean" firms have perhaps found their way on their own towards the commercialization of their technology through help from venture capitalist firms or sources other than alliance. Second, majority of alliances include biotech firms which are labeled as "Gorge" (148 alliances) or "Lagoon" (86 alliances). This demonstrates that our hypotheses on depth and breadth of technological resources are relevant, as most biotech firms in alliances are actually bound to being one of the two: either technologically deep or broad. There are, however, 132 alliances with biotech firms in "Pond" category. While our study tests the hypotheses on the whole population of firms, we also perform separate analysis limited to each of the four strategic groups and compare the results.

A comparison among the four strategic groups also highlights interesting differences: The average Deep Ocean firm is older than the average firm in any of the other three categories, consistent to our expectation that being both broad and deep means that the firm has taken many years to accumulate expertise and diversify into different fields. We also observe that alliances comprising Deep Ocean firms dealt with technologies that were three times more advanced in their development (later stage technologies) when compared to alliances with firms from the

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[3] Clearly the number of dots on the diagram is less than 379, the number of alliances after removing outliers. This is because a dot on the diagram can represent more than one alliance: Many alliances overlap on a single dot because many biotech firms with the same values of depth and breadth entered to several alliances with different Pharma firms.

other three groups. Only 14 percent of alliances with Deep Ocean firms included equity arrangements, while the number rises to 30 percent for Pond firms.

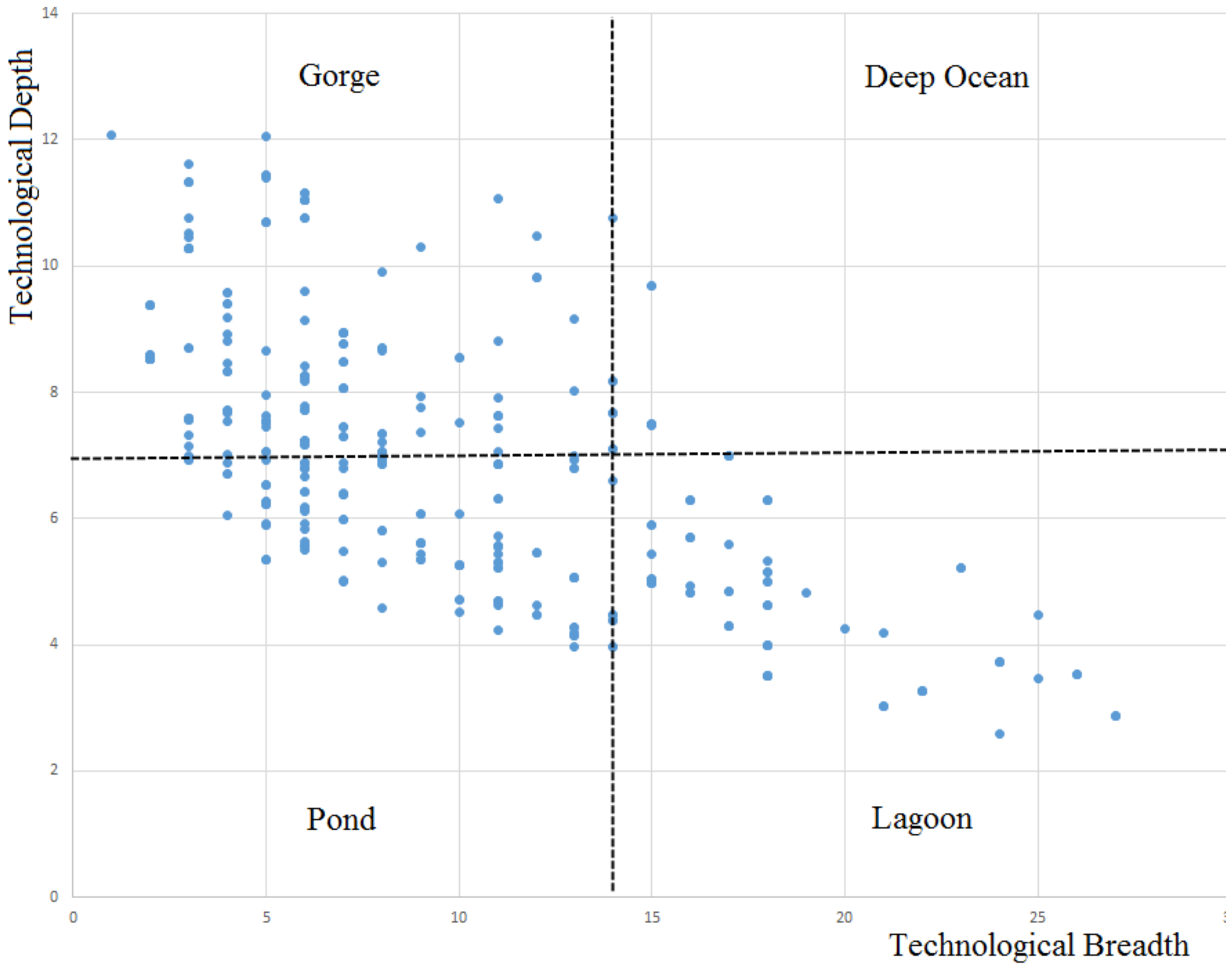

Figure 3.3: Scatterplot of all alliances in our sample, based on depth and breadth of the biotech partner's technological resources. Horizontal dotted line marks average depth (seven) and vertical dotted line marks average breadth (fourteen)

Table 3.1: Descriptive Statistics and Correlations

	Mean	S.D.	1	2	3	4	5	6	7	8
1. GOV (E=1, NE=0)	0.24	0.43	1.00							
2. STAGE	0.35	0.72	0.06	1.00						
3.AGE	17.86	4.25	0.04	0.36**	1.00					
4. FIRM SIZE	4.42	1.08	-.28**	0.14**	0.12*	1.00				
5.AGREEMENT SIZE	12.07	12.82	0.27**	0.29**	-0.10	-0.12	1.00			
6. DEPTH	6.70	2.17	0.04	0.06	0.25**	-0.30**	0.07	1.00		
7. BREADTH	10.45	7.27	-.124*	0.02	-0.16**	0.36**	-0.02	-0.71**	1.00	
8. ALLIANCE EXPERIENCE	5.44	4.17	-.28**	-0.08	-0.05	0.52**	-0.15*	-0.28**	0.32**	1.00

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 3.2: Logistic Regression Models

Dependent Variable GOVERNANCE (E=1, NE=0)	**Model 1**		**Model 2**		**Model 3**		**Model 4**	
	Beta	***s.e.***	**Beta**	***s.e.***	**Beta**	***s.e.***	**Beta**	***s.e.***
Constant	0.69	1.32	3.05*	1.81	1.58	1.94	3.60*	1.87
Control variables								
STAGE	0.32	0.27	0.35	0.28	0.42	0.29	0.36	0.29
AGE	0.06	0.05	0.05	0.06	0.07	0.06	0.07	0.06
FIRM SIZE	-0.78***	0.21	-0.72**	0.23	-0.79**	0.24	-0.74**	0.24
AGREEMENT SIZE	0.1***	0.03	0.1***	0.03	0.11***	0.03	0.1***	0.03
Independent Variables								
DEPTH			-0.24*	0.12	-0.01	0.15	-0.26*	0.12
BREADTH			-0.04	0.05	-0.07+	0.05	-0.11*	0.06
ALLIANCE EXPERIENCE			-0.13*	0.07	0.41*	0.23	-0.29*	0.13
Interactions								
DEPTH x ALLIANCE EXPERIENCE					-0.08*	0.04		
BREADTH x ALLIANCE EXPERIENCE							0.02*	0.01
Model								
Block Chi-square	46.06***		7.51*		5.77*		2.55+	
Model Chi-square	46.06***		53.58***		59.34***		56.12***	
Cox and Snell R-squared	0.24		0.27		0.29		0.28	

+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001
N=390 alliances

Descriptive statistics and correlations for the relevant variables are displayed in Table 3.1. We observe high correlations between our main explanatory variables namely breadth, depth, and alliance experience. In order to assure that multicollinearity is not an issue, we computed Value Inflation Factors (VIFs) for each pair among the three variables. None of the VIF values reached 3, indicating that we did not encounter multicollinearity.

We observe that equity type of alliance governance is negatively correlated with breadth of technological resources of the biotech firm, as well as with its alliance experience and size. It is however, positively correlated with the relative size of agreement, in accordance with the common understanding that firms accept to give up equity ownership in exchange for better financial terms. There is a strong negative correlation between technological depth and breadth, reinforcing our earlier assertion that many firms need to invest exclusively in one of these two dimensions. Among the control variables, stage and age are positively correlated, consistent with the notion that younger firms tend to enter into alliances when their technologies are still in early stages of development.

Since our dependent variable, the type of governance structure, is a dichotomous variable (equity versus non-equity), we use binary logistic regression as the method of analysis. We use hierarchical entry of independent variables in all the regressions starting with the control variables in a base model, entering the research variables in the next step and the interaction terms one by one in two subsequent steps; because an interaction effect only exists if the interaction term gives a significant contribution over and above the direct effects of the independent variables. In total, we used four models, and the results of all regressions are illustrated in Table 3.2.

First, we started with our base model which included only control variables; namely stage of technology, firm's age, firm's size, and relative size of agreement (model 1).

We then added depth, breadth and prior alliance experience to get model 2 as below:

$$GOV(E,NE) = \alpha + (STAGE.\beta 1) + (AGE.\beta 2) + (SIZE.\beta 3) + (AGREEMENTSIZE.\beta 4) + (BREADTH.\beta 5) + (DEPTH.\beta 6) + (ALLYEXP.\beta 7) + e$$

This model is where we test hypotheses 1 and 2, namely the direct effects of depth and breadth on the choice of governance. Hypotheses 3a and 3b were tested in models 3 and 4, where we entered interaction terms $DEPTH \times ALLYEXP$ and $BREADTH \times ALLYEXP$, respectively.

The control variable log of total assets (SIZE), which controls for the size of the firm, has a negative coefficient and is significant in all the four models. This seems to indicate that the smaller the biotechnology firm, the greater is the tendency of the firm to give up control to the pharmaceutical firm by entering into an equity alliance. Relative size of agreement also demonstrates a positive coefficient and significant in all the four models, which implies the same notion we derived from the correlations table: firms choose between financial gain and control in an alliance.

Results indicate a significant negative association between depth of the technology firm and equity type of governance for the alliance $(\beta = -0.24, p < 0.05)$. That means biotech firms with deeper technological resources retain greater control in the alliance through non-equity arrangements. We thus find support for hypothesis 1. The β coefficient corresponding to breadth is, however, not significant $(\beta = -0.04)$. We therefore do not find support for hypothesis 2. Whether a firm is broad or not in its technological resources seems to have no impact on the governance structure of the alliance it forms. However, when we performed the same regression analysis only limited to the firms in each of the four strategic groups, we found some significant impact of technological breadth, which we will elaborate later in section 3.4.1. The chi-square value for model 2, (Chi-square=7.51) was significant at the 0.01 level, meaning an improvement from our base model to model 2.

Model 3 included alliance experience as a moderator of the relationship between depth and type of governance. As shown in figure 3.4, we observe a significant negative relationship between interaction term $DEPTH \times ALLYEXP$ and equity type of governance, which lends support to hypothesis 3a $(\beta = -0.08, p < 0.05)$. Based on model 3, in figure 4 we have plotted the depth against values of its regression coefficient (impact on choice of governance) with and without the moderating variable alliance experience. This means that, when they have more prior alliance experience, firms with deeper technological resources tend to engage even less in equity-based alliances. We discuss this interesting finding in the discussions section.

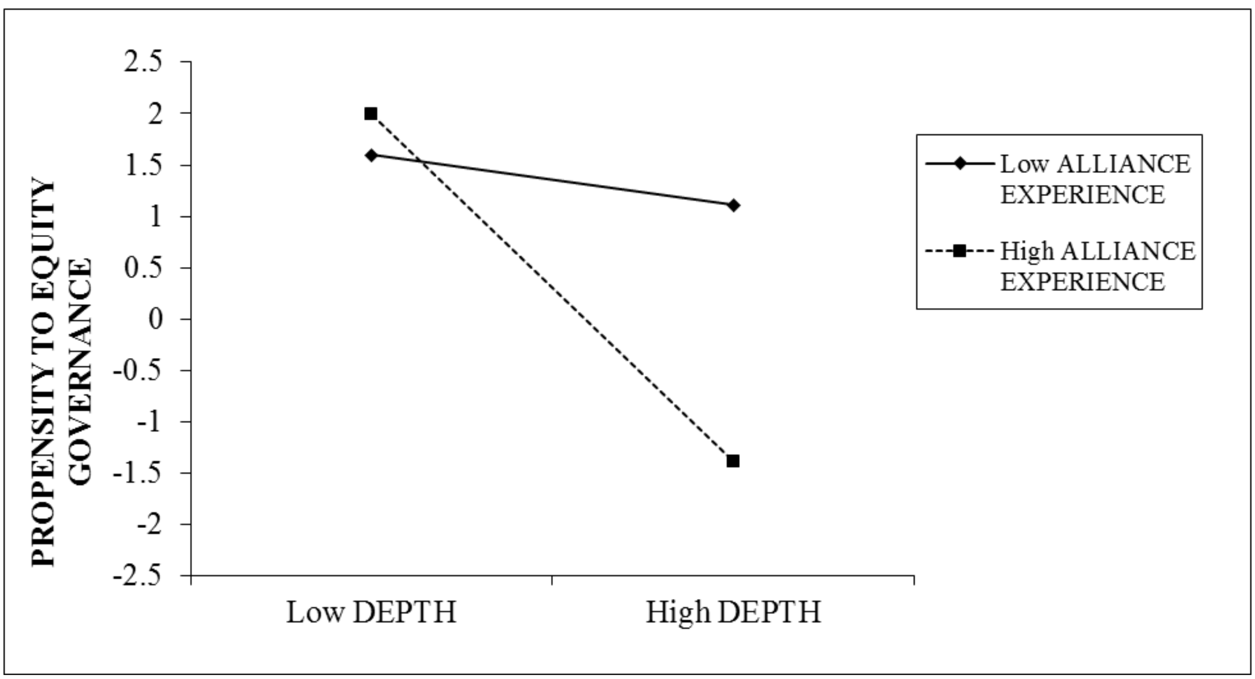

Figure 3.4: Split-plot analysis of the interaction effects of alliance experience and technological depth on the propensity to choose equity form of governance

Moving from model 2 to model 3, we observed an improvement in the goodness-of-fit as model 3 has a delta Chi-square of 5.77, p<0.05.

Model 4 included alliance experience as a moderator of the relationship between breadth and type of governance. Although breadth did not show a significant direct effect on type of governance, in both of the models with interaction effects (models 3 and 4) it does show significant negative associations with equity type of governance (contrary to what we had hypothesized). Furthermore, we find that the interaction term $BREADTH \times ALLYEXP$ shows a significant positive association with equity type of governance in alliance ($\beta = 0.02, p < 0.05$). Taken together with the statistically-significant regression coefficients obtained for breadth ($\beta = -0.11, p < 0.05$) and alliance experience ($\beta = -0.29, p < 0.05$), we find that contrary to our expectation in hypothesis 3b, alliance experience combined with breadth led to more, not less hierarchical forms of government. Our results of the analysis limited to each strategic group complement these general findings about both the direct effect of technological breadth as well as its interactive effect (breadth with alliance experience) on the choice of governance. Below we first present those results and then discuss all our findings taken together.

3.4.1 Analysis in the Four Strategic Groups

As we mentioned earlier, in addition to testing the hypotheses in the total population of alliances (N=390), we also divide the sample to four subsamples corresponding to the four strategic groups that we identified earlier, and we repeat the same statistical analysis (models 1 to 4) in each subsample. Most noteworthy results were obtained from analysis in Lagoon group (n=97) and Gorge group (n=148) which are presented in tables 3.3 and 3.4, respectively.

Unlike Gorge and Lagoon subsamples, regression analysis in Pond group (n=132) did not yield any significant results to add anything new to our understanding gained from the results in the overall sample (see Table 3.5). In Deep Ocean group (n=13) the number of observations was too little to be enabling us to infer meaningful results.

Table 3.3: Logistic Regression Models- Lagoon subsample, n=97

Dependent Variable	Model 1		Model 2		Model 3		Model 4	
GOVERNANCE (E=1, NE=0)	**Beta**	***s.e.***	**Beta**	***s.e.***	**Beta**	***s.e.***	**Beta**	***s.e.***
Constant	-3.42	2.74	-11.95*	6.32	-18.99*	9.64	-10.10+	6.72
Control variables								
STAGE	0.27	0.70	0.25	0.75	-0.17	0.81	0.08	0.77
AGE	0.21	0.16	0.24	0.20	0.25	0.26	0.25	0.22
FIRM SIZE	-0.48	0.44	-0.78	0.61	-0.71	0.73	-0.69	0.64
AGREEMENT SIZE	0.10*	0.06	0.10*	0.06	0.11*	0.06	0.10*	0.06
Independent Variables								
DEPTH			0.57	0.55	2.05+	1.35	0.63	0.57
BREADTH			0.40*	0.24	0.37+	0.25	0.26	0.30
ALLIANCE EXPERIENCE			-0.15	0.23	0.94	0.87	-0.69	0.79
Interactions								
DEPTH x ALLIANCE EXPERIENCE					-0.24	0.18		
BREADTH x ALLIANCE EXPERIENCE							0.03	0.04
Model								
Block Chi-square	10.60*		3.90		2.33+		0.50	
Model Chi-square	10.60*		14.50*		16.83*		15.00*	
Cox and Snell R-squared	0.23		0.30		0.34		0.31	

+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Table 3.4: Logistic Regression Models- Gorge subsample, n=148

Dependent Variable	**Model 1**		**Model 2**		**Model 3**		**Model 4**	
GOVERNANCE (E=1, NE=0)	**Beta**	***s.e.***	**Beta**	***s.e.***	**Beta**	***s.e.***	**Beta**	***s.e.***
Constant	3.49	2.60	12.35*	4.94	12.73*	5.44	12.06*	5.03
Control variables								
STAGE	0.47	0.48	1.14*	0.66	1.13*	0.66	1.20*	0.69
AGE	0.09	0.09	0.16	0.11	0.15	0.11	0.16	0.11
FIRM SIZE	-1.70**	0.52	-2.00**	0.69	-1.99**	0.70	-1.99**	0.70
AGREEMENT SIZE	0.09*	0.04	0.13*	0.06	0.13*	0.06	0.14*	0.06
Independent Variables								
DEPTH			-0.74*	0.31	-0.78*	0.40	-0.75*	0.32
BREADTH			-0.34*	0.19	-0.34*	0.20	-0.29	0.26
ALLIANCE EXPERIENCE			-0.38*	0.21	-0.54	1.02	-0.26	0.42
Interactions								
DEPTH x ALLIANCE EXPERIENCE					0.02	0.11		
BREADTH x ALLIANCE EXPERIENCE							-0.02	0.08
Model								
Block Chi-square	26.44***		14.41**		0.03		0.10	
Model Chi-square	26.44***		40.85***		40.88***		40.95***	
Cox and Snell R-squared	0.31		0.40		0.44		0.41	

+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Table 3.5: Logistic Regression Models- Pond subsample, n=132

Dependent Variable GOVERNANCE (E=1, NE=0)	**Model 1**		**Model 2**		**Model 3**		**Model 4**	
	Beta	***s.e.***	**Beta**	***s.e.***	**Beta**	***s.e.***	**Beta**	***s.e.***
Constant	2.91	2.22	3.71	4.86	-3.73	6.90	3.60*	1.87
Control variables								
STAGE	0.50	0.45	0.45	0.46	0.31	0.47	0.45	0.46
AGE	-0.12	0.10	-0.14	0.11	-0.08	0.12	-0.14	0.11
FIRM SIZE	-0.55+	0.35	-0.53	0.38	-0.57+	0.40	-0.53	0.38
AGREEMENT SIZE	0.14**	0.05	0.14**	0.05	0.15**	0.06	0.14**	0.05
Independent Variables								
DEPTH			-0.16	0.48	0.94	0.85	-0.17	0.49
BREADTH			0.08	0.14	0.11	0.16	0.11	0.22
ALLIANCE EXPERIENCE			-0.07	0.14	1.31+	0.89	-0.01	0.43
Interactions								
DEPTH x ALLIANCE EXPERIENCE					-0.25+	0.16		
BREADTH x ALLIANCE EXPERIENCE							-0.01	0.05
Model								
Block Chi-square	20.10***		1.01		2.66+		0.02	
Model Chi-square	20.10***		21.12**		23.78**		21.14**	
Cox and Snell R-squared	0.27		0.29		0.31		0.29	

+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001

It is interesting to note that while we did not find support for hypothesis 2, relating technological breadth to type of governance, in our general analysis, we do find such a support when considering only the population of Lagoon firms (firms that are technologically broad but not deep), as our breadth measure shows a significant positive association with equity type of governance ($\beta = 0.04, p < 0.05$. See Table 3, model 2). Yet more interesting is observing that in Gorge subsample, the direction of this effect is reversed ($\beta = -0.34, p < 0.05$. See Table 4, model 2), contrary to hypothesis 2. We discuss these findings in section 3.5

3.5 Discussion and Conclusions

Previous research has explained how knowledge and technological resources are important factors for the small technology firm's success in retaining control in alliances (Dunne, Gopalakrishnan, & Scillitoe, 2009). Our research scrutinizes these technological resources and investigates the effect of their depth and breadth on the ability of the small technology firm to maintain full equity rights while allying with a larger firm. Moreover, we explore the role of prior alliance experience in this regard.

Consistent with our first hypothesis we confirm that the deeper a firm's technology and knowledge base, the less likely it will be to form equity alliances. This is important because the small partner's knowledge or technology is a main resource involved in the alliance formation and also the core of the biotechnology firm's existence (Coombs and Deeds, 2000). Our findings are consistent with the general view of biotechnology firms as science-based firms specialized in one or few technology areas that bring their specialized knowledge to their alliances with more technologically broad-based pharmaceuticals. The deep knowledge held by the smaller biotechnology partner seems to perfectly complement the broad-based capabilities of the larger pharma partner. We find that 'the deeper the technological resources of the biotech partner in the alliance, the less the propensity to use equity in governing that alliance'. This could point to two facts: First, technologically-deeper biotech firms seem as more appealing partners to the pharmaceutical firm, such that they can enjoy an improved level of bargaining power when negotiating the alliance terms and leverage their technological depth to give-up the least amount of control rights to the financier of their R&D project. Second, pharmaceutical firms attribute more trust and confidence to the technologically-deep biotech partner, as these firms seem to be more capable of accomplishing the set goals of the project in alliance. The pharma partner might therefore insist less on taking an equity stake and obtaining a seat at the table, so to speak, because it trusts that the biotechnology partner has enough expertise to govern the alliance in the direction that meets the benefits of both partners.

Our results also suggest that the likelihood of the biotech firm to establish a non-equity alliance with the larger partner increases as the biotech firm gains more alliance experience. First, consistent with previous research (e.g. Dunne, Gopalakrishnan and Scillitoe, 2009), we found that as the biotech firm accrues more alliance experience, it is more capable of entering a non-equity alliance with the pharma partner (We did not form this as a hypotheses, since we were not interested in the direct effect of alliance experience on governance, but in its interactive effects with each of the depth and breadth dimensions of technological resources). Moreover, as we had hypothesized, we found that technologically-deep biotech firms that benefited from more alliance experience, performed better in retaining equity rights in their downstream alliances, comparing to those with less prior experience. It is not only depth of technology that signals capability of the biotech firm to its pharma partner, but the accumulation of deep technological knowledge together with alliance experience. These accumulated expertise points to both the technical capability and alliance management capability of the smaller partner, and leads to greater amounts of trust and confidence being bestowed upon it from the side of the larger pharma firm.

As to the impact of technological breadth on the type of governance, our analysis in the large sample of all alliances did not yield any significant result. It appears that in the population of alliances we studied here, whether the biotech partner was broad or not in its technological resources did not matter for the alliance set-up and governance. However, we should not draw any conclusion yet as we do find significant results when only studying each of the Lagoon (broad but not deep) and Gorge (deep but not broad) firms. We will discuss these in the next paragraph. Furthermore, contrary to our expectation, we found that the biotech firm's alliance experience combined with its technological breadth led to a more, not less, hierarchical form of government. The fact that alliance experience had opposing interacting effects when combined with depth and depth (it moderated the depth-governance and breadth-governance relationships in opposing ways), offers an avenue for further research. It could be that the broader firms have less fear of opportunistic behavior from their pharma partners, as they accrue more alliance experience, and therefore they agree to form an equity-based alliance. It is noteworthy that many of the biotech firms in our sample had previous ties with the same pharma partner. Therefore, our results could be pointing to the fact that these repeated ties leads the biotech firm to build more trust and have less fear of giving some control to the larger partner by selling equity. It could be that broader firms recognize that they do not have leverage similar to that of deeper firms in order to bargain for forming a non-equity alliance, and therefore, as they gain more alliance experience, they learn that it is better to go for more financial capital in exchange for giving away equity rights to the pharma partner. Our results, however, cannot confirm this as we do not know how many repeated alliances (i.e. alliances with the same pharma partner) a given biotech firm has, neither do we know if broader firms had more repeated ties than other firms. We'll further discuss this limitation of our study in section 3.5.2.

Finally, as we performed the same regression analysis in each of the four strategic groups, we found some interesting results. While we did not find the expected positive association between technological breadth and equity type of governance in our total population, we found such a relationship when limiting our analysis to Lagoon sub-sample, i.e. firms that are broad but not deep. When all the firms are relatively broad and relatively shallow in their technological resources, the breadth dimension of the biotech firm's technology seems to strongly affect the type of governance towards an equity-based one. This could point to the fact that the broader firm has less fear over opportunistic behavior from the side of the pharma partner, as it has diversified its knowledge base over a broad range of areas and is less concerned about relinquishing control in a partnerships that deals only with a few of its areas of expertise.

Moreover, in the Gorge sub-sample, i.e. among firms that are technologically deep but not broad when compared to other firms, we found a negative association between technological breadth and equity type of governance. This means that when the technology firm is deep enough in its technological resources, i.e. the larger partner is assured about its specialized expertise, then not only the breadth dimension of the firm's technology is not detrimental, but it is also beneficial in helping the deep firm to retain control right and form a non-equity alliance.

3.5.1 Contributions to the literature

Our study sheds light on the less known characteristics of technology firms and proves them to have an impact on the governance of the alliances made by these firms. We highlight the importance of distinguishing depth and breadth of technological knowledge when studying alliance relationships. Past research has found that technical capital, knowledge base or technical competence, may be a biotechnology firm's major source of leverage when forming an alliance with a resource-rich pharmaceutical company (e.g. Ahuja, 2000; Dunne, Gopalakrishnan and Scillitoe, 2009; Gopalakrishnan, Scillitoe and Santoro, 2008). We build up upon and add to these research by suggesting that the depth and the breadth dimension of these technological resources can have differing impacts in the alliance relationship. Therefore a biotechnology firm's source of leverage can be decomposed into "depth" and "breadth" dimensions and be further scrutinized as these dimensions seem to separately influence alliance-level measures such as alliance governance.

Making the distinction between depth and breadth of technological knowledge can also help explain some contradicting findings in the biopharma alliance literature, for example regarding the impact of technological resources of the smaller biotechnology firm on the amount of financial capital it acquires from the pharma partner upon entering an alliance (e.g. Gopalakrishnan, Scillitoe and Santoro, 2008; Stuart, Hoang, & Hybels, 1999; Coombs, Mudambi, & Deeds, 2006)

3.5.2 Limitations and Future Lines of Research

Despite its contributions, our study has a number of limitations which offer avenues for future research: First, as we formed our dependent variable as a binary (equity versus non-equity alliance), our study does not distinguish how much equity the alliance partner gives up in an equity alliance. If the amount is very small, it may have different implications than if it's a large amount of equity rights given up in the alliance.

Second, we solely focus on US alliances between biotech firms as technology providers and pharma firms as clients. Results might not be generalizable to other countries and other types of vertical alliances. A future line of research could study the phenomenon in a broader settings with more heterogeneity among the technology firms.

Third, as we saw earlier when discussing our findings, we got mixing results as to the impact of the biotech firm's prior alliance experience and how this experience moderates the relationship between knowledge dimensions and alliance governance. Due to data limitation, we did not distinguish between alliances that a biotechnology firm forms with a repeating partner and those with a new one. By making this distinction, future research can explain the mixing findings of our study regarding the moderating role of prior alliance experience. As we elaborated on credibility and trust as a mechanism that leads to less contractual complexity when firms ally, we saw that repeating ties and new ties can have opposing impacts on choice of governance. Several new ties that the focal biotech firm has made in the past, enhances its credibility and reputation in the marketplace, and therefore can have a positive impact on its effort to form non-equity alliances. On the other hand, repeated ties with the same partner can help a biotech firm desperate for financial capital to easier trust that pharma partner in an equity-based alliance and obtain the needed capital. Therefore, in such situations repeated ties with the same partner can lead to occurrence of equity type of alliance.

3.5.3 Implications for Practice

Managers of new technology firms must make sure that their knowledge resources are both effectively and efficiently developed and exploited. Knowledge and technological resources are the core of these firms' existence and often the main resources involved in alliances, especially with downstream partners (Coombs and Deeds, 2000).

Managers of new biotech firms need to recognize the differing potential roles of knowledge depth and breadth when adopting their knowledge strategy. Developing in-depth knowledge and expertise can further lead to patents granted to the firm. Patents are a sign of the firm's success and accomplishment (Coombs et al. 2006), helping it in attracting financial capital from venture capitals and/or alliance partners, and, as explained by our research, also helping the firm to retain control in the alliance by not giving away equity rights. We believe that the empirical results of this study can shed light on the less known characteristics of technology resources that are important for managers of science-based firms when adopting their knowledge strategy. With limited resources, small technology-based firms need to invest only in the right type and right dimension of technological knowledge: the one that brings them highest returns and most leverage in their inter-firm linkages.

Chapter 4
High Technology Firms and Collaborative Innovation: The Impacts of Alliance Strategy, Breadth and Depth of Knowledge Application

Chapter 4: High Technology Firms and Collaborative Innovation: The Impacts of Alliance Strategy, Breadth and Depth of Knowledge Application

4.0 Abstract

The focus of this chapter of the dissertation is on the impact of firm's engagement in upstream technology alliances, i.e. alliances mainly with universities and research centers, on innovative outputs it gains from all its inter-organizational collaborations. In chapter 2, we discussed how the focal technology firm's depth and breadth of knowledge relate to both its downstream and upstream alliances. Then, in chapter 3 we focused on downstream alliances and empirically tested hypotheses on the relationships between the focal firm's knowledge configuration and alliance structure. In this chapter our objective is to complement the previous two chapters by focusing mainly on a firm's orientation towards upstream vertical alliances, while investigating how depth and breadth of the firm's knowledge application domains relate to its alliance innovative outputs. In doing so, we first study the direct effect of the firm's depth and breadth in applying technological knowledge on the innovative outputs it reaps from its collaborative efforts, and then we take a next step to see how the firm's orientation towards university alliances comes into play and moderates this effect.

A major difference of this chapter compared to chapter 3 is the sample of firms we study: Instead of North American publicly-traded biotech firms and their alliances with large pharmaceutical corporations, in this chapter we focus on a sample of Spanish biotechnology firms, typically young and small -both in assets and number of employees- which engage heavily in upstream research and development collaborations with universities. Even when allying downstream, many of these firms form horizontal alliances, e.g. joint product development arrangements, with other firms at the same level of the value chain. Others provide day-to-day

services for their clients or engineer new equipment. The different business models that they follow and the essential difference as to their alliance activities when compared to the sample of North American firms, made us adopt a different theoretical approach to study their inter-organizational collaborations. Here, unlike the previous chapter, we are dealing with a greater amount of knowledge transfer between partners. We will see how this difference calls for a theoretical approach that focuses on alliances as means of 'learning' and 'knowledge acquisition', and not merely as vehicles for 'knowledge access'.

Results of our study in this chapter show that while the firm's depth in applying knowledge exerts a clear negative influence on innovative outputs from alliances, the effect of an orientation towards university alliances appears only in combination with the depth of knowledge application. This combined effect is so strong as to reverse the effect of depth on innovative outputs, meaning that firms which tend to ally more with universities can positively leverage their depth in order to achieve more innovative outputs from their collaborations.

4.1. Introduction

Small firms that compete in high technology industries encounter major challenges in their constant pursuit of survival and profitability (Zahra, 1996; Liebeskind, Oliver, Zucker and Brewer, 1996). In comparison to firms in traditional industries, firms in high-tech sectors need to face shorter span of product life cycle, higher uncertainties, heavier R&D investments and more intense competition (Kobrin, 1991). In comparison to larger firms, small firms lack sufficient resources to secure long-term survival and pursuit of operations. They need to innovate continuously and exploit first-mover advantages as entry barriers for protecting their innovations (Qian and Li, 2003). While there is an increasing global demand for high-tech products and services, the opportunities for profitability and growth also abound in these industries, and the risks of failure are high (Qian and Li, 2003). Firms therefore need to act entrepreneurially to bring together and use their resources in ways that lead to continuous innovations and sustained competitive advantage (Barney, 1991).

Access to the resources needed for building strong innovative and organizational capabilities, however, remains a challenge for firms in science-based industries (Zahra, 1996). Firms need to access and utilize diverse technological capabilities, and accumulating these capabilities is a time-consuming, expensive, and uncertain process (Teece et al., 1997). Firms, therefore, need to develop strategic relationships with the suppliers of these scarce resources (Oliver and Liebeskind, 1998). For example, relationships with established and reputable organizations such as leading research universities can positively impact a new firm's legitimacy as viewed by other powerful stakeholders (Mian, 1997). These upstream collaborations with universities also give the firm access to diverse resources, sometimes at prices lower than the going market rates, which in turn enable the firm to reduce its costs and improve performance (Geisler, 1995; Matkin, 1990).

On the other side, universities have become increasingly proactive in their commercialization endeavors in the recent years (e.g. Di Gregorio and Shane, 2003; Stuart, Ozdemir and Ding, 2007). Many universities now seem to have expanded their traditional mission of educating students to a broader mission that includes patenting and commercialization of research advancement (Bok, 2009; Perkmann, Neely and Walsh, 2011). Trends in patenting activities of universities are extensively documented in works of researchers such as Henderson, Jaffe, and Trajtenberg (1998), Mowery, Nelson, Sampat, and Ziedonis (2001) and Sampat (2006), among others.

Similar to many other emerging industries, the biotechnology industry contains a wide range of organizations that vary in their ownership and missions (Zucker et al., 1998). Innovation and technology development in biotechnology sector have united coordinated efforts of three types of organizations: universities, biotechnology firms, and established life sciences firms (Kenney, 1986; Arora and Gambardella, 1990; Liebeskind et al., 1996; Powell et al., 1996; Zucker et al., 2002; George et al., 2002). As is evident, the knowledge and expertise tend to be disaggregated in the eco-system. Biotechnology is by definition an area of knowledge-intensive activity and its development requires complementary assets that reside in these three different types of organizations. Universities are the source of basic scientific knowledge and new breakthroughs. Then, in many small biotechnology firms, we see the commercial application of university knowledge and the ability to translate the specialized academic knowledge into different types of products and applications. Finally, established life science companies have experience in large-scale production, expertise with product approval and regulatory process, as well as with marketing and distribution. Most importantly they have the substantial financial resources required to complete the process. Strategic research alliances are therefore formed to bring these complementary competencies together (Audretsch and Feldman, 2003).

The alliance literature has been more focused on collaborative partnerships of biotech firms with downstream life sciences companies, e.g. pharmaceuticals. However, there exists also a growing body of research on university-industry relations that studies the extensive connections between biotech firms and universities upstream to their activities (Gittelman and Kogut, 2003). While the previous chapter of this dissertation dealt with the former types of partnerships, this chapter tries to capture the effect of the latter type of partnership, i.e. vertical upstream alliances of focal biotech firms[4] with universities and research institutions, where the firm seeks access to valuable scientific and technological knowledge (George et. Al., 2002; Powell et al., 1996; Rothaermel and Deeds, 2006; Santoro & Gopalakrishnan, 2015).

Prior research on university-firm alliances has extensively investigated the impact of such linkages on firm-level outputs, e.g. innovative and financial performance, patenting activity and rate of new product development (e.g. George, Zahra and Wood; 2002; Perkmann, Neely and Walsh, 2011; Santoro & Gopalakrishnan, 2015). Research findings have also confirmed the positive impact of upstream alliances with universities on knowledge transfer and assimilation and the focal firm's propensity to form and ability to benefit from subsequent downstream alliances (Stuart, Ozdemir and Ding, 2007; Rothaermel and Deeds, 2004; Rothaermel and Deeds, 2006). However, research on how firms can find strategies to leverage the depth and breadth of their knowledge base within university-firm alliances has been scarce (Lin and Wu, 2010) A new and growing body of research investigates the role of knowledge depth and external knowledge sourcing strategies on the firm's ability to bring about innovations (Al-laham, Amburgey and Baden-Fuller, 2010; Denicolai, Ramirez, and Tidd, 2014; Lin and Wu, 2010). Our study aims to contribute to this growing body of research by first evaluating how the depth of knowledge application, the breadth of knowledge application, and orientation toward university alliances exclusively impact the firm's ability to transfer and absorb knowledge and bring about innovations as an output of its collaborative efforts. More importantly, we explore how external knowledge-sourcing oriented towards universities can help the firm better exploit its focus on applying knowledge, i.e. what we call 'depth of knowledge application', in order to obtain better innovative outputs.

[4] From this point on, by the term 'firm' we mean 'focal biotech firm'.

Based on the above and given an insight that we got from the previous two chapters of this dissertation, i.e. the usefulness of distinguishing between depth and breadth of the focal firm's knowledge-related resources; the primary research question we address in this chapter is: How does allying with universities help firms better leverage their knowledge-based resources to achieve higher innovative performance? More specifically, we first ask how depth and breadth of the focal firm in applying knowledge exclusively affect the overall innovative output it reaps from its inter-organizational collaborations. We also explore if and how the mere engagement in more upstream alliances with universities affect this overall innovative output. Then, we take things one step further by addressing our main research question that we pointed out earlier: How does the focal firm's orientation towards allying with universities, as opposed to allying with other firms, come into play to affect the relationship between the firm's depth[5] and its overall alliance innovative outputs[6]? In other words, in this chapter we treat the focal biotechnology firm as the unit of analysis and analyze how its alliance innovative output varies as a result of its relative focus on one or few knowledge domains as well as its academic-orientation when it comes to outsourcing knowledge.

Our objective in this chapter is therefore to complement the previous two chapters by focusing mainly on a firm's tendency towards upstream vertical alliances, while accounting for the role that depth and breadth of knowledge application can have in such alliances. In doing so, we cover the whole "tripartite alliance chain" (Stuart, Ozdemir and Ding, 2007) where the focal biotech firm serves as a value-added intermediary between universities and downstream alliance partners (e.g. Rothaermel and Deeds, 2004; Haeussler, Patzelt and Zahra, 2012). By providing

[5] From this point on, by depth we mean 'the focus of the firm in applying knowledge across technological areas'. Similarly, by breadth we mean 'the diversity of the firm in applying knowledge across technological areas'
[6] Throughout this chapter, by 'alliance innovative output' we mean total innovative output obtained when the focal firm partnered with another organization (firms, universities/research centers, …)

further empirical support, our research contributes to the growing body of research that studies the effectiveness of knowledge-sourcing strategies and how firms can best leverage their internal resources in combination with external partnerships.

The rest of the chapter proceeds in the following way: In section 4.2 we first present the theoretical foundations of our study and discuss how Knowledge-based view serves as the proper framework to investigate university-firm collaborations. Then we argue why we hypothesize relationships between firm's depth, breadth, and orientation towards university alliances on the one hand and the innovative outputs it gains from inter-organizational collaborations, on the other hand. After presenting all the hypotheses, in section 4.3 we discuss the research methods we employed, the data we collected and the construction of research variables. Then in section 4.4 we empirically test the hypotheses and present the results. Finally, in section 4.5 we conclude this chapter by discussing the findings, as well as the limitations of this study and suggestions for further research.

4.2 Theoretical Background & Hypotheses

As mentioned in the introduction of this dissertation, we base our analysis of university-biotech firm collaborations in the Knowledge-based View (KBV) of the firm. According to this view, 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, inter-organizational collaboration can be viewed as an instrument for the firm to improve its competitive position by exploiting new opportunities, including opportunities to generate or adopt innovations (Grant and Baden-Fuller, 1995).

In this section we intend to justify the use of Knowledge-based View as the proper theoretical approach to address our analysis of university-firm partnerships. We discuss how university-firm collaborations are seen with the KVB lens. Based on this, we then justify how KVB serves as the proper theoretical framework for this chapter of the dissertation.

4.2.1. University-Firm Collaborations According to Knowledge-based View

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 such as strategic alliances. As attested by Grand and Baden-Fuller (1996) “the 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”.

It is known that transferring and integrating knowledge takes place most efficiently within the focal firm, such that market contracts only serve as efficient mechanisms when the knowledge is embedded in a product, and using the product by the buyer does not require access to the embedded knowledge (Demsetz, 1991, Kogut and Zander, 1992; Grant, 1996). Then, if tacit knowledge – i.e. the type of experience-based knowledge that cannot be adequately articulated by verbal means and is therefore difficult to transfer from an individual to another (Polanyi, 1966)- is transferred and integrated more efficiently within the company, and the market serves as an efficient mechanism to transfer and integrate embedded knowledge; the question is: under what circumstances are collaboration agreements superior to both the firm and the market? (Grant and Baden-Fuller, 1995). This question becomes particularly relevant to our study when we note that in biotechnology sector: 1) Tacit rather than explicit knowledge is the industry norm (Al-Laham and Amburgey, 2005), and 2) the knowledge required for research breakthroughs far exceeds the capabilities of any single firm, forcing firms to pursue a diverse set of inter-organizational collaborations with other players in the marketplace (i.e. upstream, downstream and horizontal to their core activities) in order to obtain the needed expertise (De Carolis, 2003; Powell et al., 1996)

To answer to the above question we refer to the review on Knowledge-based theory of strategic alliances that we provided in chapter 2. Briefly, the following circumstances point to why a collaboration agreement (e.g. between the focal technology firm and a university upstream to its activities) is a mechanism for knowledge integration superior to both the firm and the market: First, because the range of knowledge required for a given product is typically very wide, and most of this knowledge is not product-specific. In biotechnology industry, few firms possess the whole range of required knowledge for producing their products. Second, given that knowledge acquisition and integration is a time-consuming process, firms need to invest in a project whose future knowledge requirements are uncertain and the knowledge itself has uncertain returns a. 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 (Grant and Baden-Fuller, 1995). Third, industries subject to rapid technological change are characterized by first-mover advantages. 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 required to create and integrate knowledge, on the other hand. In such situations, inter-organizational collaboration can offer a solution given that innovation in a firm usually implies transfer of knowledge originated in another firm, or in our case, originated in universities and research centers.

Based on what we said, universities in are an important source of external knowledge as firms look to renew their sources to access science based ideas (Link, et al., 2007). Moreover, competitive environments have become more intense due to expanding global reach and rapidly changing technologies (Etzkowitz, et al., 2008). In response, many firms have downsized and specialized in fewer areas and, consequently rely more on external sources to access and exploit complementary and supplementary knowledge retaining their distinctive specialized knowledge (Grant and Baden-Fuller, 2004; Santoro and Chakrabarti, 2002). Firms often collaborate with universities to gain access to groundbreaking basic and pre-competitive research that can be melded and combined with their existing knowledge to create new products and innovations (Bishop, D'Este and Neely, 2011; Jelinek, 2010). Universities are preferred partners when there are concerns about the perceived ability to fully appropriate the results. Especially, firms that pursue exploratory R&D strategies in-house are found to be interested in funding university-based exploratory research projects in order to extend their internal search efforts (Bercovitz and Feldman, 2007).

4.2.2. Hypotheses Development

In this chapter, we treat biotechnology firms as the unit of analysis and analyze the heterogeneity among them with regard to allying with universities, as well as the impact these alliances make on their innovative outputs. Analyzing a large sample of Spanish biotechnology firms and their alliance activities, we observed heterogeneity in the firms' number of university alliances as well as their innovative performance. Several factors could have contributed to this heterogeneity, for instance, past research has associated the heterogeneity in firm's propensity toward university alliances, to a firm's age; arguing that older firms are less dependent on university alliances, since, in addition to university linkages, they have established other connections and relationships in the industry with other biotech firms (including suppliers and clients) as well as pharmaceutical firms (e.g. Rothaermel and Deeds, 2004 and 2006; Hess and Rothaermel, 2011). However, younger firms mainly seek access to knowledge and technology originated in universities' research projects, in order to further take those knowledge and technology to revenue-generating ends. Past research has found that younger firms and firms with weak knowledge depth seek to enhance their knowledge base and accumulate knowledge in core technology areas through both internal R&D and external search, e.g. by acting as knowledge seeker in university alliances (Lin and Wu, 2010; Rothaermel and Deeds, 2006). As these young technology firms mature and benefit from a stronger knowledge depth, they tend to lower internal R&D intensity and shift their strategic resources to obtaining desirable partners in downstream alliances and acquisitions (Hoang and Rothaermel, 2010; Lin and Wu, 2010; Rothaermel and Deeds, 2004).

In chapter 3 we found that the depth of the focal biotechnology firm's technological knowledge influences the structure of alliance governance. Similarly, in this chapter we expect the depth and breadth of R&D activities undertaken in the focal biotech firm to affect the overall innovative outputs resulting from its alliances. In other words, we expect that whether a firm is focused on one field of technological application or diversified into several fields, will have differing impact on innovative outputs.

Before formulating the hypotheses of our research it is indispensable to clarify the scope of our study. As mentioned earlier, in this study we pay particular attention to the firm's upstream alliances with universities. However, the scope of our study is not limited to them. We consider a random population of firms who may or may not have entered to university alliances.

With prevalent instances of such alliances, however, this population provides a proper setting for our study, because the heterogeneity across firms in terms of engagement with upstream partners ranges from no engagement at all to slightly, moderately, or heavily focused towards such partnerships. We'll further discuss the characteristics of our data sample in section 4.3.1. For now, it is important to note that we focus our attention on the biotechnology sector in the level of a European country (Spain), which differs significantly from the North American counterpart in terms of competition, access to financial capital, size of firms and fields of their activity. Therefore, we form our hypotheses knowing that the focal biotech firm mainly enters to two types of alliances: Vertical upstream alliance with universities and horizontal downstream alliances with other firms.

Horizontal alliances are established when the technology firm collaborates with other organizations at the same level of the value chain (Haeussler and Patzelt, 2008). These relationships are primarily joint product development arrangements and they give the firm new knowledge in the design, prototyping, testing, development, and introduction of new products. Due to the fact that the firm is exposed to multiple and diverse sources of ideas and knowledge, these alliances are believed to foster further innovation (George, Zahra, Wheatley and Khan, 2001). Horizontal alliances enable the firm to reduce demand uncertainty, gain strategic flexibility, and provide customers with a wider range of services (Burgers et al., 1993; Smith and Barclay, 1997).

In the light of the two previous paragraphs, it is reasonable to expect that the amount of knowledge transfer between the partners in either type of alliance, whether upstream with universities or horizontal with other firms, is high. Unlike vertical downstream alliances, in upstream alliances the biotech firm is in the 'receiving end' of the transfer of knowledge and technology. Moreover, research has found that compared to downstream alliances, in upstream alliances with universities the amount of knowledge transfer between the two partners and the learning occurred on the seeker side (here, focal biotech firm) are considerably higher (Al-laham, Amburgey and Baden-Fuller, 2010). Taken together, this means that these university alliances or horizontal partnerships are not anymore mere ‘knowledge-access alliances’ (Grand and Baden-Fuller, 2004), but a vast majority of them are formed with the intention to absorb and learn partner’s knowledge (Stuart, Ozdemir and Ding, 2007). Therefore, the absorptive capacity of the seeker firm, here: focal biotech firm plays a crucial role on how effective the knowledge is transferred and how much the firm benefits from the alliance. Absorptive capacity is associated to the level of prior related knowledge (Cohen and Levinthal, 1990: 128). By drawing on prior related knowledge and providing the relevant cognitive structure, absorptive capacity allows the firm to better assimilate and recognize the usefulness of external knowledge (Zahra and George, 2002; Larrañeta, Zahra and Galan, 2007). Past research on inter-firm collaborations has found 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 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 alliance partners. We know that technological innovation stems from combining technological components in a novel way or reconfiguring existing components (De Boer, Van den Bosch, and Volberda, 1999). Past research has found that having multiple knowledge domains leads to the combining of knowledge in ways that yield innovations (Taylor and Greve, 2006). Although we are projecting the dimensions of breadth (and depth) on the application, rather than on the possession of knowledge, it is reasonable to consider a firm broad in application of knowledge if it possesses broad knowledge resources.

Research on organizational learning has found that firms that are exposed to heterogeneous contexts and environments benefit from exposure to diverse ideas and experiences that allow for thinking "out of the box" (Levinthal and March, 1993; Levitt and March, 1988) and, hence, for developing more elaborate knowledge (Penrose, 1959). In the same fashion, firms that build on and use a diverse range of knowledge are able to produce innovations consistent with the aggregate path of technological development in their industry (Hargrave and Van de Ven, 2006; Tushman and Anderson, 1986, Vasudeva and Anand, 2011). Previous empirical research has found support for these idea that broader knowledge leads to more innovation; for example, Baum, Calabrese, and Silverman (2000) and Powell, Koput, and Smith-Doerr (1996) found that, on average, biotechnology firms with more diverse alliances were also more successful. These studies highlight the advantages offered by technologically diverse knowledge.

Moreover, breadth of knowledge application, defined as the number of application fields addressed by a firm's technological resources, provides a means for the firm to benefit from economies of scope, because it can apply the same technology in different application fields or adapt that technology from one field to another (Durand, Bruyaka and Mangematin, 2008). Previous research has found that technological diversity (typically expressed as the diversity of a firm's patent portfolio) is an antecedent of rent-generating resources (Sampson, 2007) and performance (Nesta and Saviotti, 2005).

Biotech firms can leverage their knowledge by linking projects across biotechnology subfields and therefor increase their product innovation and research output (Shan, Walker, and Kogut, 1994). In other words, the valuable exploitation of rare knowledge can benefit from exploration into different application domains. In biotechnology industry, most firms concentrate their technological application in one field (e.g. human or animal health, agri-food, environmental, etc), though some firms diversify into multiple fields (Durand, Bruyaka and Mangematin, 2008). Based on the above, we expect these diversified firms to bring about more innovations as a result of engaging in 'learning' alliances:

Hypothesis 1:. *Breadth of knowledge application in a biotech firm has a positive effect on the innovative output of its alliances*

However, investing in broad knowledge is not all what it takes for a biotech firm to benefit from its 'learning' alliances. It is true that investments in the breadth of knowledge determine the extent to which knowledge will be overlapping with a learning partner. Nevertheless, investments in deep knowledge are required too, in order to boost learning performance and to allow a firm to learn about more complex matters (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998; Van Wijk, 2003).

A specialized firm is focused in applying knowledge in its field, and has developed deep knowledge and core competencies, in the form of technical or professional expertise. It therefore tends to engage in activities in its existing, specialized domains (Christensen, 2006). As a result, the firm is able to develop increasingly efficient processes and routines that sustain its current focus (Zhou and Li, 2012). In other words, 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). Recent work of Zhou and Li (2012) has found that when compared to a firm with broad knowledge base, a firm with a deep knowledge base is better able to achieve radical innovation through enhanced market knowledge acquisition rather than internal knowledge sharing.

Although in this study we are dealing with depth and focus in applying knowledge over application fields, it is reasonable to expect such a focused firm (in application) to also possess a deep, rather than broad, knowledge base. Depending on the extent that the biotech firm acquires its partner's knowledge, it might need to further develop an early-stage technology to bring it closer to commercial ends. Only a deep knowledge base can enable the firm to do so, therefore:

Hypothesis 2: *Depth of knowledge application in a biotech firm has a positive effect on the innovative output of its alliances*

As compared to alliances with other firms, alliances with universities are commonly associated to higher trust between partners, and therefore, an enhanced quality of interaction (e.g. Wathne, Roos and von Krogh, 1996). Research has shown that trust contributes to greater knowledge exchange between alliance partners (e.g. Kale, Singh and Perlmutter, 2000) and positively affects the efficiency of a research alliance because it facilitates the learning process and the transfer of knowledge itself (Madhok, 1995). On the other hand, relationships with other firms, as opposed to relationships with universities, involve a risk of knowledge appropriation and the loss of valuable intellectual property.

Firms are also encouraged to engage in alliances with universities because they can leverage their R&D funding: Quiet often government funding is available to firms for research projects conducted in collaboration with universities (Grimaldi and von Tunzelmann, 2002). Small and resource-constrained biotech firms may achieve substantial financial leverage for collaboration with universities (Bayona Saez et. al, 2002; Perkman, Neely and Walsh, 2011). As an example, the R&D expenses of US biotechnology firms that engaged in alliances with universities were found to be lower and these companies were found more innovative than those without such ties (George et al., 2002). As universities are home to explorative basic research and exploration leads to more innovations, we expect a biotech firm that engages in alliances with universities to be more innovative in all its collaborative efforts.

Hypothesis 3: *Biotech firms oriented to allying with universities rather than with other firms gain more overall innovative output from their inter-organizational collaborations.*

When leveraging strategic alliances as external sources of new knowledge, a firm's main challenges are assimilation and application of new external knowledge, rather than creating new knowledge (Grant and Baden-Fuller, 2004; Lane et al., 2001). Access to a knowledge source does not equal acquisition of external knowledge. Although strategic alliances expose the focal firm to wide variety of ideas, inter-firm learning through which knowledge flows are transferred between partners does not necessarily take place (Grant and Baden-Fuller, 2004; Inkpen and Dinur, 1998; Xia and Roper, 2008). From the viewpoint of the "receiving end" of knowledge flow (Foss and Pedersen, 2004), an organization's ability to learn from partners is the most critical factor that moderates a firm's ability to absorb incoming knowledge in strategic alliances (Foss and Pedersen, 2004; Lyles and Salk, 1996; Lin and Wu, 2010).

Extant body of empirical research supports that the effectiveness of inter-firm learning is highly influenced by a firm's ability to learn from partners. Such ability has been sometimes constructed as knowledge depth and breadth (Prabhu et al., 2005). Our conceptualization of depth in applying knowledge closely relates to a firm's ability to absorb partner's knowledge in a given field. Because university alliances often deal with highly complex knowledge and advanced scientific breakthroughs, the transfer of knowledge from such alliances are only possible when a firm enjoys a deep knowledge base and accumulated expertise in the field. Past research also supports that firms with in-depth knowledge are likely to facilitate transferring higher-level technological capabilities (Kotabe et al., 2003, Lin and Wu, 2010). As we said earlier, we believe that upstream alliances with universities are of 'learning' type, meaning that the focal firm typically intends to absorb and learn knowledge generated in the university.

Hypothesis 4*: Academic-orientation in alliance portfolio positively moderates the relationship between a biotech firm's depth of technology application and its alliance innovative performance.*

4.3. Research Methods

4.3.1. Research Design and Sample

As we mentioned earlier, we focused our research and hypotheses on the biotechnology industry. This rapidly growing industry has a strong focus on science-based basic research that requires inputs from different streams of specialized knowledge (Hamilton, 1996). Due to its knowledge-intensive nature, the biotechnology industry has become an attractive setting for studying new product development processes (Shan et al. 1994), strategic alliances (Kotabe and

Swan, 1995; Liebeskind et al., 1996; Powell et al., 1996), R&D outsourcing decisions (Pisano, 1990), innovative output (Austin, 1993), and organizational competence (Henderson and Cockburn, 1994; George, Zahra and Wood, 2002).

To study the role of academic-orientation in the firm's alliance strategy, we need a sample of firms actively engaging in alliances with research centers and universities. We therefor begin with a sample of Spanish biotechnology firms –which are typically small and young, average firm has around 40 employees and is about 9 years old- based on information from ASEBIO (Spanish Association of Biotechnology Companies) database.

As we mentioned earlier, we needed to adopt our approach in accordance with the characteristics of this population: First, in a non-North American context, new biotechnology firms tend to follow heterogeneous business models as a result of their differences in scientific involvement and their access to public stock markets (Mangematin et al., 2003). If instead of focusing on Spanish biotech industry, we were selecting our sample from a population of all European countries, it would be relevant that were mainly involved with human therapeutic technologies were selected. But, as Durand, Bruyaka and Mangematin (2008) posit when studying French biotech industry, at the level of a single European country such a selection makes less sense. Firstly because there are a few high-powered biotech companies, and second, because many private companies participate in the industry but do not receive money from public investors. Finally, because in some European countries, other fields of application apart from human therapeutics are prevalent as well and form a major proportion of total biotechnology activities, such as agriculture, agri-food and animal health (the data we collected confirmed that this is also the case for Spain).

Moreover, our approach in this study departs from the common habit of research that focuses on knowledge-related variables through patent data analysis (such as the depth and breadth configuration we conducted in chapter 3) or scientists' careers and publications (Owen-Smith and Powell, 2001). Instead, we are interested in the degree to which the focal firm diversifies (as opposed to focusing) in one or more domains of activity (e.g. industrial and environmental applications, agri-food, bio-informatics, human and animal therapeutic), therefore, we must include all organizations in the field. Moreover, following recommendations of previous research (e.g. George, Zahra, Wheatley and Khan, 2001; Gulati, Lavie and Singh, 2009) we expect that there must be interactions, and perhaps synergies, between different alliances of the focal firm, in terms of learning and strategic objectives. Therefore, we consider that a firm's propensity toward university alliances can affect the overall innovative outputs it reaps from interfirm collaborations, because "goal-oriented management of the alliance portfolio—all the alliances of the focal firm—plays a decisive role in company performance" (Hoffmann, 2007). Excluding firms that don't have any alliance with universities would create a selection bias and risk biasing the statistical tests. Also, limiting our measure of innovative output merely to those obtained from university alliances would hinder an understanding of alliances as a portfolio of interconnected relationships of the focal firm.

After building a dataset of Spanish firms, we considered only those firms that have biotechnology as their main activity, leading to a population of 285 firms. Data were collected through a personal survey in 2012 and 2013. The survey questionnaire was addressed to the CEO and/or the person responsible for R&D activities in the firm, and the respondents were asked to answer questions regarding all of the alliances the firm had established in the last 5 years. After collecting the answers and eliminating those cases with missing data, we obtained a final population of 94 firms for which we had all information on the number and type of partners they had (university or firm) in all of their alliances in the 5 year window, which provided a usable response rate of 33%.

4.3.2 Measures

Dependent Variable: As we mentioned above, the dependent variable of this study is the innovative output of the firm's portfolio of alliances. We measure this by the number of patents resulting from all the firm's alliances (whether with universities or with other firms) in the last five years.

We use patent data as we follow the research efforts of several other scholars who have used patents as measure of innovative success of both organizations and inter-organizational collaborations (e.g. Henderson and Cockburn, 1994; Jaffe, Trajenberg and Henderson, 1993; Rosenkopf and Nerkar, 2001; Al-Laham, Amburgey and Baden-Fuller, 2010). However, we acknowledge that there are a number of potential limitations of using patent data. These limitations are discussed in secion 4.5.2.

Independent Variables:

Breadth of knowledge application is the number of application fields addressed by the firm's technological resources, ranging from 1 to 5. More precisely, these fields include four technological fields: 1. Industrial/environmental, 2. Agri-food, 3. Human and animal health, 4. Bioinformatics, and the fifth category is "Services and others". We included 'services' as a category to capture for the firm's engagement in more services-oriented, rather than research-oriented activities as we knew providing such engineering services might be an essential part of the firm's business model. Results, however, did not show any difference with or without considering this category. We kept it in the measure, however, to account for a firm's possible strategy to diversify the use of its knowledge not only across technological fields but also to services.

The average firm in our sample got a value of 1.86 for its breadth in applying knowledge[7], with the maximum value being 5 and the minimum being 1, obviously.

Depth of knowledge application is the number of R&D employees divided by breadth, as described above. This measure captures the degree to which a firm is focused on a particular application field. In other word, "the number of R&D personnel per field" counts for the relative strength of the firm's knowledge resources when dispersed among different fields. Using number of employees as part of the proxy for a knowledge-related variable is consistent with previous research that posits "specialist knowledge resides in individuals" and "the role of management is to coordinate the integration of this knowledge" (e.g. Grant, 1996).

Our calculated measure of depth yielded an average of 7.65 for each firm, where the deepest firm had 81 R&D staff per each application field, and the shallowest firm had only 1 R&D employee responsible for three fields, hence scoring a value of 0.33. The average firm in our sample has around 11 R&D staff in total.

Academic alliance orientation is the ratio of university alliances of the firm to all alliances it has entered in the past 5 years. This ratio could serve as a proxy for a firm's alliance policy, whether it is more inclined to allying with universities or with firms. This means, the

[7] The fact that the mean value was this close to the minimum possible value, is one of the limitations of our breadth measure that we acknowledge and further discuss in section 4.5.2

value of this measure is equal to one minus the share of firm's alliances with other firms. The more the firms is oriented to ally with universities, the less it is inclined toward entering into alliances with other firms.

Control Variables:

Firm Size is the total number of full-time employees in a firm, whereas *R&D department size* is measured by the number of permanent employees in the R&D department as reported by firm's respondents. *Firm Age* is the number of years elapsed since foundation of the firm. Finally, *External R&D expenditure* was measured as expenditure on R&D as average percentage of the total income of the company for the past 5 years (Perez-Luño and Valle-Cabrera, 2011).

4.4 Analysis and Results

Descriptive statistics and correlations for the relevant variables are displayed in Table 3.1. We observe significant correlations between our dependent variable, alliance innovative output, and the variables controlling for age, R&D size and external R&D expenditure, as well as a high and significant correlation between alliance innovative output and the explanatory variable depth. We also observe significant negative correlation between two of our explanatory variables namely depth and breadth, suggesting that the broader the firm the shallower it is and the deeper the firm, the narrower it is, as a direct consequence of the way we constructed the two measures. However, because of this correlation and also a marginally significant correlation between academic alliance orientation and depth, we had to make sure that multicollinearity among our explanatory variables is not an issue. In order to verify this, we computed Value

Inflation Factor (VIF) for these three variables, pair by pair, and the maximum value we obtained was 1.02, well below the acceptable threshold of 3. This means that multicollinearity is not an issue.

Table 4.2 provides the results of our hierarchical regression analysis where three linear regression models were created: Base model to test the effect of control variables, independent model to test our independent variables, and contingent model to test the combined effect of depth and academic alliance orientation. We used hierarchical entry of variables because a combined effect only exists if the interaction term gives a significant contribution over and above the direct effects of the independent variables.

Table 4.1 Descriptive Statistics: Means, standard deviations, and correlations [a]

	Mean	S.D.	1	2	3	4	5	6	7	8
1. Alliance Innov. Output	2.46	3.66	1.00							
2. Firm Age	8.71	6.78	0.33**	1.00						
3. Firm Size	40.64	107.65	0.14	0.54***	1.00					
4. R&D Size	10.71	14.28	0.42***	0.54***	0.67***	1.00				
5. Ext. R&D Expenditure	7.98	17.00	0.21*	-0.12	-0.09	-0.09	1.00			
6. Breadth	1.86	0.90	0.02	-0.07	-0.06	-0.11	-0.20*	1.00		
7. Depth	7.65	12.29	0.39**	0.53***	0.50***	0.92***	-0.03	-0.32**	1.00	
8. Acad. Alliance Orientation	0.59	0.26	-0.04	0.27*	0.28*	0.17*	-0.02	0.00	0.14+	1.00

[a] N=94

+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Table 4.2 Hierarchical Regression Models [a]

Dependent Variable	**Base Model**		**Independent Model**		**Contingent Model**	
Alliance Innov. Output	**Coefficient**	**t statistic.**	**Coefficient**	**t statistic.**	**Coefficient**	**t statistic.**
Control variables						
Age	0.588**	3.083	0.588**	3.135	.413*	2.021
Firm Size	-1.539**	-2.841	-1.869**	-3.484	-1.632**	-3.030
R&D Size	1.077*	2.014	5.452**	3.478	4.654**	2.934
Ext. R&D expenditure	0.256*	2.273	0.308**	2.781	0.310**	2.860
Independent Variables						
Breadth			-0.050	-.414	-0.001	-0.009
Depth			-3.068**	-2.953	-5.004**	-3.498
Acad. Alliance. Orientation			-0.066	-0.167	-.248	-0.625
Firm Alliance Orientation			-0.026	-0.066	-0.086	-0.224
Interactions						
Depth x Acad. Alliance. Orientation.					1.671*	1.938
Model						
R^2	0.226		0.338		0.378	
Adjusted R^2	0.177		0.248**		0.282*	
F statistic	4.606**		3.764**		3.919**	
Change in R^2			0.112**		0.40*	
Change in F			2.487*		3.754*	

[a] N=94, regression coefficients are standardized
+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Our base model shows that all our control variables have a significant effect on innovative output, and this effect is consistent among all the three models. Older firms, firms with more staff engaged in R&D activities, and firms that spend a larger proportion of their income on R&D activities seems to gain more innovative output from their inter-organizational collaborations. On the contrary, larger firms appear to be less innovative in their alliances.

The independent model, shown in the next column, makes a significant contribution over and above the base model (change in $R^2 = 0.112$, $p<0.01$). Here, we can see that breadth doesn't have any significant impact on innovative output from alliances, hence, we do not find support for Hypothesis 1. Moreover, although we find a significant impact of depth on the dependent variable, this effect is in the opposite direction of what we had hypothesized in Hypothesis 2. Depth of a firm in applying knowledge seems to have a negative impact on the alliance innovative output. We will discuss this interesting finding in the discussion section. Furthermore, hypothesis 3 is also rejected as we do not find a significant relationship between orientation to ally with universities and obtaining more innovative output from alliances. However, our most noteworthy finding appears in the contingent model, where we do find support for hypothesis 4. Only when combined with depth of applying knowledge, a firm's tendency to ally with universities positively impacts the overall innovative output of collaborations. Our contingent model, which studies this interactive effect, makes a significant contribution over and above the main effects (change in $R^2 = 0.40$, $p<0.05$), and the regression coefficient for the interaction between depth and academic alliance is positive and significant ($\beta=1.671$, $p<0.05$). This suggest that introducing academic alliance orientation and combining with depth, reverses the (negative) effect that depth by itself had and changes it to a positive impact on the dependent variable, as shown in figure 4.1.

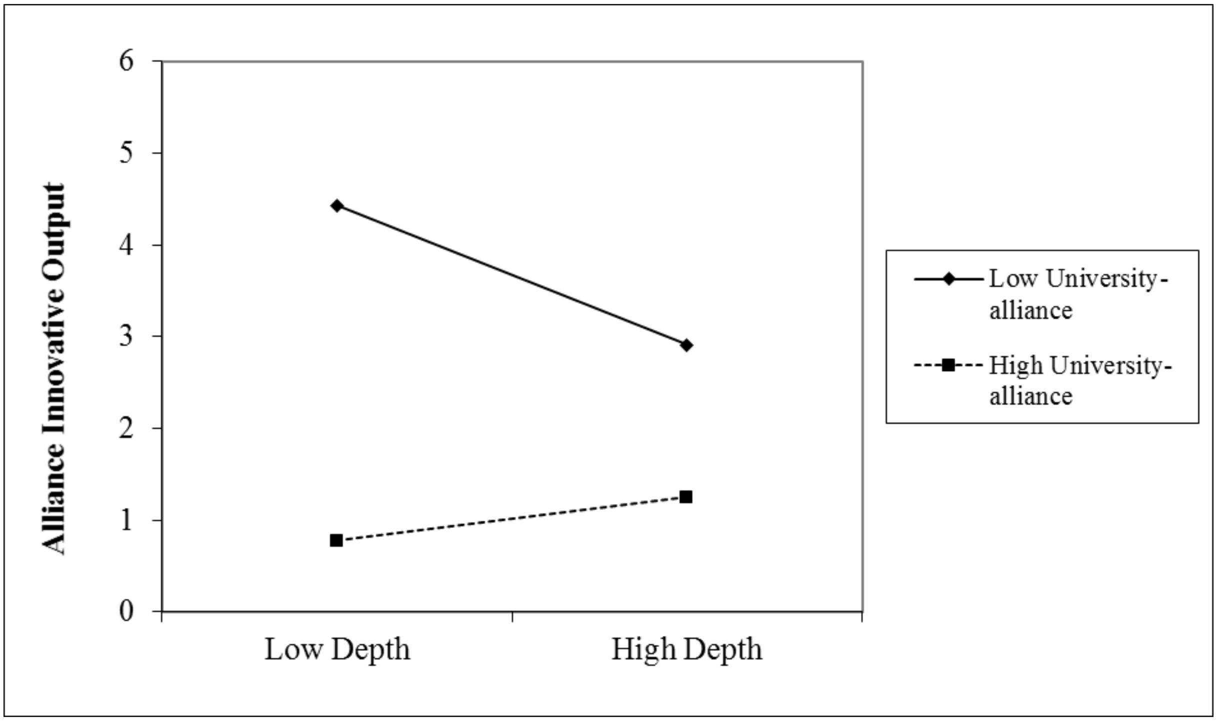

Figure 4.1. Split-plot analysis of the interaction effects of a firm's alliance orientation and depth of applying knowledge, on the overall innovative output of its alliances

4.5 Discussion and Conclusions

Much of the existing literature on strategic alliances implicitly positions biotechnology firms at the upstream pole of the pharmaceutical (or agricultural biotechnology) industry value chains. That is to say, biotechnology firms are understood to be where the technology originates, which is then taken further to the marketplace by strategic partnerships (Robinson and Stuart, 2007; Stuart, Ozdemir and Ding, 2007). However many biotech firms maintain close links with universities, which has led researchers to pay attention to university-firm collaborations (see for example, Liebeskind et al., 1996; Audretsch and Stephan, 1996; Powell et al., 1996; Zucker et al., 1998; George et al., 2002). Indeed, with just a few exceptions, most of the drugs on the market with biotechnological origins have emanated from license agreements for scientific discoveries made in universities (Edwards et al., 2003). This study investigates the links between a technology firm's focus and diversity in applying knowledge (i.e. depth and breadth) and the innovative outputs it reaps from inter-organizational partnerships, while paying particular attention to the role of university alliances in this regard. Instead of North-American bio-pharma industry and 'knowledge-access' alliances, we directed our attention to the European context and we studied a sample of Spanish firms who engaged in alliances where knowledge-acquisition from the partner, rather than knowledge-access, was a primary reason to collaborate. Their partnerships can take both the form of a vertical upstream alliance as well a horizontal one (Durand, Bruyaka and Mangematin, 2008).

We found a negative relationship between depth of applying knowledge and the innovative output from alliances, on the contrary to our expectation. This could mean that, generally speaking, firms don't need to be deeply focused in only one or few fields of application, if they are looking to obtain more patents from their alliances. Therefore, we associate this finding mainly with our measure of innovative outputs, i.e. number of patents, which has a number of limitations that we'll further address in section 4.5.2. Our finding could also mean that deep firms are not seeking to file patents as an outcome of their alliances. Because of being deep, they might be able to do more in-house research and development on their own and advance the technology-based projects enough to be able to gain exclusive rights over it, without sharing those rights with other partners or without having to spend their R&D Euros externally in exchange for patent rights. Then, they can probably take that developed knowledge further down the value chain with the help of downstream alliances. Another alternative explanation could be that deep firms might consider product development, rather than patenting, as their expected goal from the alliance.

The main finding of our study is obtained when considering both the results of hypothesis 2 (depth is negatively related to innovative output) and hypothesis 4 (combined effect of depth and orientation towards university alliances is positively related to innovative output). In other words, we find that firms which are more interested in allying with universities leverage the focus that they have in applying knowledge in order to obtain more innovative outputs. However, firms without such interest, seem to follow a different path, and even if they have focused their R&D resources over fewer fields, they don't seem to obtain more innovative outputs from their partnerships, at least as far as patents are concerned. We find that a tendency toward partnering upstream with universities per se does not lead to more innovative outputs (hypothesis 3), but only when combined with depth, as we mentioned. This could mean that, since university alliances imply considerable transfer of knowledge between partners (Rothaermel and Deeds, 2004), considerable depth and focus on specializing in an application field play a crucial role in such a transfer. In fact, only firms that are heavily focused on the relevant field of alliance, benefit from their university alliances by obtaining more innovative results. Consistent with findings of previous research, this could imply that external knowledge sourcing through universities may not work for technology firms with inferior knowledge depth (Lin and Wu, 2010). Also, since the knowledge transferred in biotech firm-university alliances is mainly tacit, it is only effectively transferred when the receiving end, the firm, possesses enough focus, depth, and expertise in the field; or in other words, it has the required absorptive capacity.

We did not hypothesize an interaction effect of breadth and tendency to university alliances on the innovative output. In 'learning' alliances with universities, depth, rather than breadth, in applying knowledge is expected to play a role, as discussed in the previous paragraph, because such intense in-flow of tacit knowledge requires prior absorptive capacity. Although breadth of knowledge base is also used in many studies as a proxy for absorptive capacity (e.g. Cohen and Levinthal, 1990; Van Den Bosch, Volberda, and De Boer, 1999; Van Wijk, 2003) we should be aware of the fact that our measure of breadth is different from that in the mentioned studies. We are mainly measuring how broadly the firm *applies* technological knowledge across real-world fields of use, while those studies measure the breadth of the underlying knowledge domains in which the firm has expertise.

Another aspect to point out is that our measures of breadth and depth, unlike in chapter 3, are not exclusive in this chapter. This means we consider that if a firm is deep, it is not broad by definition, and vice versa. All these being said, it results that although in the literature both breadth and depth can point to absorptive capacity of a firm, in our study of young and small biotechnology firms only the depth measure captures such concept, as it refers to the amount of R&D-related resources a firm is able to dedicate to a given field (Larrañeta, Zahra and Galan, 2012). Our measure of breadth seems to be addressing the ability of a firm to diversify its use of knowledge and enjoy economies of scope by applying the same knowledge across several fields.

4.5.1 Contributions to the Literature and Implications for Practice

Our research offers a new understanding of academic alliances and the role of firm's technology configuration. We show that a combination of engagement in academic collaborations and a strong depth in R&D resources, helps the firm toward gaining more innovative results from its alliances. Past research has paid little attention to this combined effect of depth and alliance strategy (Lin and Wu, 2010). Our research therefore contributes to the growing body of work in technology management that evaluates the effectiveness of knowledge-sourcing strategies and how firms can best leverage their internal resources in combination with external partnerships. We bring more evidence to validate the finding of previous research that allying with universities has differing and opposite effects on the focal firm's patenting ability, than allying with other firm (see: Al-Laham, Amburgey and Baden-Fuller, 2010)

Managers of small biotech firms need to cautiously adopt their alliance strategy as these are often essential part of the firm's strategic planning and crucial for its competitive advantage. Our study sheds light on how firms should look at their internal R&D resources and choose their alliance strategy accordingly.

4.5.2. Limitations and Future Research

Our research has several limitations, addressing which paves the way for future research. First of all, other measures apart from number of patents could explain innovative output and the complex issue of innovation performance. With the data collected through our survey, it was difficult to distinguish between goals of alliances and assess whether or not the firm's goal of entering into an alliance included or implied filing patents. Firms might not be willing to reveal detailed information on the outcomes of their partnerships, especially if those were regarded as failures, because this can damage their credibility and hence their success in attracting subsequent desired alliance partners.

Our measure of breadth also suffered from not being enough fine-grained. This could be the reason why we did not find the hypothesized relationship between breadth of applying knowledge and innovative outputs, since some of the categories in our questionnaire were too broad, for example, we did not distinguish between human and animal health and medicine.

Future research can take our work as an initial step towards distinguishing between depth and breadth of knowledge resources, and, if provided with data on the amount of knowledge transfer in the dyad-level, it can explore whether these two dimensions of knowledge-based resources play different roles in each type of alliance. Based on the knowledge we had from the industry, we assumed that many alliances of the focal firms included considerable transfer of knowledge. However, in the absence of dyad-level data, we could not quantitatively evaluate the degree to which an alliance is of knowledge-acquisition as opposed to knowledge-access type.

Finally, knowledge types in different subfields can be different in terms of complexity (Carayannopoulos and Auster, 2010). Research has pointed to the differences in levels of knowledge complexity and specificity across subfields within biotechnology (Al-Laham and Amburgey, 2005), whereas knowledge types have found to matter for a firm's propensity to patent (Perez-Luño and Valle-Cabrera, 2011). Future research can consider types of knowledge and merge them into our study of knowledge depth and breadth and their effect on performance measures. For example, in a study of Spanish and European patenting activities, Perez-Luño and Valle-Cabrera (2011) find that a combination of R&D expenditures (internal versus external) on the one hand and type of knowledge on the other hand, affects a firm's propensity to patenting. Future research could do a similar study in the context of technology alliances to dig further into how depth and breadth of knowledge provide firms with leverages in different situations and with different types of knowledge in question.

Chapter 5

Conclusions

Chapter 5: Conclusions

For many years following the publication of Schumpeter's groundbreaking work "The Theory of Economic Development" in 1934, researchers had been conducting studies that revolved around and confirmed Schumpeter's argument: "Innovation is the stronghold of large firms". Empirically, this was supported by the correlation between firm size and R&D inputs (measured as employment of scientists and engineers) (Shan, Walker and Kogut, 1994). However, further research found a different relationship between R&D outputs (e.g. patents and inventions) and firm size. For example, small firms were found to possess a percentage of total patents in the industry greater than their share of sales (Acs and Audretsch, 1989). Rather than concluding that large firms are less productive in R&D, this result can be interpreted in that the resources if large firms support innovation in affiliated small firms. Nowadays, this is the case in many emerging high-technology industries, where small firms not only rely on resources from larger established companies, but they also benefit from scientific and technological advances generated in universities and public sector research centers. Biotechnology, nanotechnology, and microelectronics are among some of the industries with most instances of inter-organizational collaborations for technology development.

Biotechnology includes techniques for manipulating micro-organisms. In its modern form, it uses the techniques of molecular biology to manipulate the basic building blocks of living organism for a specific use. Because the sources of knowledge are vast and dispersed, and because product development success is highly uncertain, the biotechnology industry is scene to many inter-organizational collaborations, where different types of firms interact with each other and with universities and research centers, to cover the value chain of biotechnology products while minimizing risk and R&D costs.

In this dissertation, we closely examined knowledge resources of the focal biotech firm and studied how these resources relate to the firm's alliances both with universities as well as with pharmaceutical firms. In chapter 2 we illustrated how biotech firms can be divided in four groups based on structuration, i.e. depth and breadth, of their knowledge base, and how by paying attention to this structuration we can explain alliance behavior and outcomes. Then in chapter 3 we found that it is not only depth of technology that signals capability of the biotech firm to its pharma partner, but the accumulation of deep technological knowledge together with alliance experience. Therefore, the biotech firms that were more successful in retaining control in alliances with larger pharma partners were those who had deep technological knowledge together with credibility and prestige as a result of having previous alliances. In chapter 4 we found that firms which are more inclined toward allying with universities, as opposed to allying with other firms, leverage the focus that they have in applying knowledge in order to obtain more innovative outputs.

Taken together, the findings of this dissertation not only highlight knowledge structuration and its role in alliances, but also contribute to the literature in many ways: First, our study contributes to the literature on strategy and technology management by showing how the strategic choice regarding depth and breadth of a technology firm's knowledge base relates to the outcome of its alliance governance negotiations. Also, we showed that firms in different strategic groups as to the depth and breadth of their knowledge resources, exhibit different behavior in leveraging depth and breadth to retain control in alliances. This calls for future research to further explore the underlying mechanisms that lead to such different behaviors. Subsequent research can also verify our results and their generalizability by testing our hypotheses in other contexts.

Moreover, we take an initial step on the way to understanding how depth and breadth of knowledge application in the focal firm combines with its university alliances. While we recognize the limitations of this part of our research, we believe that the theoretical foundation developed here contributes to our understanding of firm-university linkages. The theory and arguments that we presented can be used to test knowledge, technology and alliance relationships with more fine-grained data.

Another interesting suggestion for future research is to use longitudinal data and study the evolution of a firm's knowledge base, to observe how its dimensions of depth and breadth evolve over time. The change in patterns of depth and breadth can be associated to the firm's alliance activity. In this vein, future research can take depth and breadth as dependent variables and inter-firm collaborations as the influencing factor. Different type of alliances - i.e. exploration or exploitation alliances, knowledge access or knowledge-acquisition alliances - are expected to affect the firm's depth and breadth of technological knowledge in different ways. In fact, an evidence of knowledge transfer taking place between partners is whether or not the receiving firm's knowledge base has changed as a result of partnership.

Furthermore, future research can incorporate the view of pharmaceutical firm into our setting. That means, similar measures of depth and breadth of technological resources can be built for the larger pharma partner; and then the interplay or match between knowledge configuration of the two partners can be investigated to find out the most effective and efficient mutual configurations in terms of achieving alliance goals or higher performance.

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