Depth and Breadth of Knowledge and the Governance of Technology Alliances

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Abstract

This paper focuses on technology alliances between R&D intensive biotechnology firms and larger pharmaceutical companies. It aims to investigate whether the biotech partners can leverage the depth and the breadth of their knowledge resources to retain their equity ownership when forming an alliance, and whether prior alliance experience adds to their overall leverage. Using a sample of 390 alliances formed between US biotechnology and pharmaceutical companies, we find that biotech firms with deeper technological resources are more likely to retain their equity ownership, and that this relationship is stronger when the biotech firm has more alliance experience.

Keywords: Knowledge Depth, Knowledge Breadth, Alliances, Governance, Biopharma

1. Introduction

Strategic management scholars have studied the conditions under which firms are most likely to adopt organizational governance forms such as markets or hierarchies (e.g., Monteverde and Teece,1982; Walker and Weber, 1984), hierarchies or alliances (e.g., Pisano, 1990), and equity or non-equity alliances (e.g., Oxley, 1997). Broadly speaking, alliance governance involves choosing between equity and non-equity forms, also referred to as quasi-hierarchies and quasi-markets, respectively. 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 and Singh, 1998).

The choice of governance structure in technology alliances has been the subject of a variety of studies (e.g. Bosse and Alvarez, 2010; Das and Teng, 2000; Oxley and Sampson, 2004). Most of these studies are based on the assumption of bounded rationality, i.e. that managers cannot make accurate estimations on the future value of an alliance. Therefore, governance choices are made based on an estimation of the value to be gained and on risks to be avoided due to uncertainty (Pateli, 2009). Research has found that valuable R&D capabilities of the technology firm and the characteristics of knowledge involved in the alliance significantly impact the choice of governance (e.g. Carayannopoulos and Auster, 2010; Dunne et al., 2009; Oxley and Sampson, 2004). However, several questions remain unexplored: In research-intensive industries, the link between technological resources -the main asset brought into alliance- and the governance structure needs further examination (David and Han, 2004; Dunne et al., 2009; Garcia-Canal et al., 2008; Phene and Tallman, 2012).

It has long been known that small and resource-constrained technology firms are exposed to the risk of expropriation when partnering with significantly larger firms (Aghion and Tirole, 1994). Past research has found that new technology ventures with small resource endowments and private information about valuable projects will be forced to exchange ownership of their projects at a suboptimal price (Lerner and Merges, 1998). Empirical work, e.g. by Rothaermel (2001) and Lerner et al. (2003), reaffirm this notion by finding that a substantial amount of the value created through small firm and large firm alliances was appropriated by the larger partners.

A frequent example is the alliance that a biotech firm with drug discovery and development projects forms with a large established pharmaceutical in order to finance its R&D projects and access

downstream capabilities. When negotiating contractual terms of such alliances, the pharma and the biotech firms often have differing objectives: While the pharma firm looks for control over the intellectual property, the biotechnology firm prefers contracts with greater rights accruing to itself (Ozmel et al., 2017). Control rights and value-capturing rights in biopharma alliances are not merely reflected in the form of governance structure. Control rights include a wide spectrum ranging from governance, disposition of patented and unpatented information, and control of clinical trials and subsequent activities (Higgins, 2007). Hence, depending on the contract, equity ownership may or may not be a sufficient indicator of control rights[1]. There has been little empirical research to investigate how technology firms with different configurations of technological resources choose to retain equity ownership or to (partially) sell it in exchange for otherwise lacking resources.

To address the gap in the research literature, we focus on the focal biotechnology firms, recognizing that they can be both deep and broad in their technological knowledge, neither broad nor deep, only broad, or only deep (Srivastava and Laplume, 2014), and we will elaborate on the alliance activity of any given firms in each of these situations. “Depth” refers to the accumulated expertise in a specialized technology area, while “breadth” refers to the technological diversity or the scope of technological activities (Bierly et al., 2009; Zhang and Baden-Fuller, 2010). Managers of all these firms are faced with two different challenges: First, they need to make choices on the extent of depth and breadth of knowledge development when strategically planning their scientific activities (Zahra and Covin, 1993; Lin et al., 2006; Lin and Wu, 2010). Second, they often need to form alliances with larger pharma firms; and may be faced with the choice of giving up equity ownership in exchange for the needed resources or capabilities from the larger partner. The question arises as to how they leverage their own knowledge resources and keep their equity and yet gain the required resources. This leads us to the focal research questions: How do depth and breadth of the technological resources of the biotech firm affect governance structure in an alliance? Can the depth and the breadth provide a firm with leverage to get desirable partnership terms? Do more experienced firms exploit these dimensions better?

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[1] Some researchers have argued that when one party takes an equity interest in its alliance partner, it possesses more extensive control rights than in a non-equity alliance (e.g. Bosse and Alvarez, 2010; Pisano, 1989). Others rely on detailed contract provisions that specify all claims on control rights, and even rights to unexpected outcomes, regardless of the governance structure (Ozmel et al.,2017). While the latter type of information was not accessible for the alliances we are studying, we limit our discussion to equity versus non-equity based structures, without claiming that we are necessarily capturing the amount of control rights in this way. Nevertheless, we acknowledge that "in theory" these two structures could imply different levels of control: *"As contingencies arise, [equity] ownership becomes important because it conveys residual rights of control or the right to control decisions that have not already been set by a contractual agreement"* (Pisano, 1989).

The literature on strategic alliances has viewed governance through a number of theoretical lenses, namely: The Transaction Cost Economics (TCE), where efficiency considerations form the primary driver of the choice of governance (e.g. Williamson, 1975; Pisano, 1989). With increased uncertainty about partner opportunism, the control mechanism present in hierarchical forms is preferred over market-based approaches (Oxley, 1997). The Resource-Based View (RBV) of the firm, which is used to describe the conditions under which it is optimal to coordinate specialized resources in a hierarchical structure (e.g. Conner and Prahalad, 1996; Oxley and Sampson, 2004). Real Options (RO), which suggests that the ability to flexibly update an investment plan conditional upon the arrival of new information is valuable; and this value is not accounted for in traditional theories of investment or governance (Leiblein, 2003). By initiating an alliance, a firm gains access to a growth option for future expansion or to acquire its partner, while maintaining the option to defer complete commitment (Folta, 1998; Vassolo et al., 2004).

Based on both TCE and RO foundations, our paper relates the depth and the breadth of technological resources of the firm to the governance of the alliance. TCE suggests that firms prefer more hierarchical governance because of the superior incentive alignment and control, "especially when there is uncertainty about partner intentions or task requirements" (Pisano, 1989). In contrast, RO suggests that "under technological uncertainty", firms prefer the flexibility of less hierarchical governance, which provides them the ability to make future discretionary investments while avoiding irreversible set-up, administrative, and dissolution costs (Folta, 1998; Santoro and McGill, 2005). We will argue that deep or broad technological resources represent different types of uncertainties and investment possibilities and hence relate to different choices of governance mode. We build on and add to both TCE and RO-based explanations of governance in technology alliances by arguing that each of these two frameworks can be beneficial in describing a different setting of equity-based alliances: TCE better explains firms concerns in joint equity alliances (i.e., joint ventures) while RO is more useful when studying direct (minority) equity alliances (Pisano, 1989)[2].

This study makes two main contributions to the streams of research on technological knowledge and alliances: First, it speaks to the literature on technology alliances by highlighting the roles of depth and breadth of knowledge as drivers of alliance-level outcomes. Second, it divides biotechnology firms into

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[2] Although our empirical data does not include joint ventures (as we will elaborate in section 3.2.) we still provide a theoretical underpinning for both joint equity alliances as well as minority equity participations, as we emphasize the distinction between the two mechanisms. As Pisano (1989) puts it, joint equity alliances are where both parties share ownership and decision-making in the alliance itself, while minority (or direct) equity participations happen when there is an alliance contract combined with a purchase by one party (e.g. the large pharma company) of some of the other party's (e.g. the biotech firm's) common or preferred shares.

four groups based on how their technological knowledge is structured across (breadth) and within (depth) knowledge domains. In doing so, it contributes to the literature on knowledge management by finding that the effects of depth and breadth are not the same across the four groups of firms. It is informative for managers to know in which group their company is positioned and therefore how they could leverage the depth or breadth of their knowledge.

It is commonly believed that in most biotech-pharma alliances, the big pharma partner chooses among many potential biotech partners (Mason and Drakeman, 2014). There is also evidence that biotechnology firms with partners significantly larger than themselves can still have bargaining power to meet their interests when the two parties have opposing views on governance (Dunne et al., 2009). Therefore, although the objectives and insights of both partners are important, the focus of this study is on the biotech firm and its perspective of alliance governance since it has sufficient influence and decision-making power in the negotiation process.

The rest of this paper proceeds as follows: Section 2 presents the theoretical background that leads to hypotheses development. Section 3 discusses the research methods and, section 4 empirically tests the hypotheses and presents the results. Finally, section 5 concludes this study by discussing its findings as well as its limitations and future lines of research.

2. Hypotheses Development

2.1. Four Strategic Knowledge Groups

Figure 1 divides the biotech firms into four groups based on their knowledge strategy emphasis (Srivastava and Laplume, 2014; pg. 95). We label these four types of firms using the analogy of bodies of water. 1) The first type, the so called ‘Ocean’ firms, 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 that 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 that 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.

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Insert Figure 1 around here

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We expect ‘Pond’ firms to enter into alliances with larger pharma partners in a somewhat disadvantageous position. On the other hand, ‘Ocean’ firms are the resource-rich biotech firms that they rarely need alliances with larger pharma firms. They are probably large enough to have developed broad and deep knowledge bases, and perhaps they would obtain financing from venture capitalists and other sources. We therefore expect to see more alliance activity in ‘Lagoon’ and ‘Gorge’ groups and seek to find out if alliance governance differs across these two groups.

We first introduce hypotheses that are inclusive of all firms with their depth or breadth measures, it would also be helpful to suggest additional hypotheses that explicitly compare the strategic knowledge groups. We will call these the "complementary hypotheses", which are conceptually different from but based on the same reasoning as the main hypotheses.

2.2. Technological Depth and Alliance Governance Structure

Small firms typically prefer less hierarchical governance modes for fear of losing their autonomy, while, based on the Resource-based View of strategic alliances (e.g. Das and Teng, 2000), large firms prefer more hierarchical alliances to have greater power over the resources and the final outcome of the collaborative process (Tether, 2002).

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 and 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 broad-based pharma partner often seeks access to a specific technology, drug target or group of potential drugs (Zhang et al., 2007). It is therefore expected that biotech firms with deeper technological resources would seem more appealing to a potential pharma partner, as being technologically deep is a sign of focusing the limited resources on specific domains of excellence. Empirical research has found that non-equity based structure for 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).

From the point of view of the pharma firm, the TCE perspective suggests that a deep, rather than broad biotech firm poses less behavioral risk: Most biotech alliances involve exchange of tacit know-how, making it difficult for the financier to verify that a partner's day-to-day efforts are allocated to the alliance rather than to other activities (e.g., investigating other drug targets). A deep biotech firm, however, does not have a multitude of options outside the alliance scope to work on, hence the pharma partner would see less need for a close monitoring through hierarchical governance.

Moreover, biotechnology alliances face a great deal of technological uncertainty: For example, novel combinations of technologies and lagged development of complementary related technologies can make a potential technology application irrelevant within a new and rapidly changing technological system (Fleming, 2001). An alliance with a deep biotech firm is particularly subject to such technological uncertainty because the firm is not able to quickly and flexibly respond to changing environment or unexpected outcomes. The RO view suggests that under conditions of high uncertainty about the viability and the success of the investment, firms are more likely to opt for less hierarchical forms of governance to assure flexibility and avoid the cost of irreversible investments (Barney and Lee, 1998; Pateli, 2009). This means that when partnering a deep biotech firm, the high costs of alliance formation, organization and dissolution make hierarchical governance less attractive for the pharma partner (Santoro and McGill, 2005; Steensma and Corley, 2001).

All in all, specialized knowledge of a technologically-deep biotech firm is particularly sought after, giving the firm more bargaining power and ability to retain ownership. The uncertainty considerations of the pharma firm are also in line with such preference. This leads to our hypothesis:

> *H1.* The deeper the technological resources of the biotech firm, the less likely it is to sell equity to the larger pharma partner when forming an alliance.

Gorge firms are deeper in their technological resources than both Pond and Lagoon firms. Ocean firm are as deep as Gorge firms, but depth is not their main characteristic because they are also broad. With the same reasoning as for the previous hypothesis, we can expect Gorge firms to be less likely to end up in equity-based alliances

> *H1.Complementary:*
>
> The Gorge type of biotech firm is less likely to sell equity to the larger pharma partner when forming an alliance

2.3. Technological Breadth and Alliance Governance Structure

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 to respond to a changing environment (Bierly and Chakrabarti, 1996; Srivastava and Gnyawali, 2011). The strategic alliance literature has provided empirical evidence for the value of a broad knowledge base in alliance formation (e.g. Zahra, Ireland and Hitt, 2000; George, Zahra and Wood, 2002). Researchers have found that established, multi-technology, R&D-intensive firms are very capable of absorbing new knowledge generated outside firm boundaries.

A pharma firm sees a potential for opportunistic behavior in a broad biotech partner: While it is difficult to verify that the resources are employed in the direction specified by the agreement, the broad firm can work in a wide range of knowledge areas outside the scope of the alliance. According to the TCE view, more hierarchical alliance modes are favored when appropriability hazards are high due to difficulty in specifying or limiting the scope of technology underlying the alliance (Oxley, 1997).

On the other hand, broader firms are better equipped to face the technological uncertainty inherent in biotechnology development projects. The diversified knowledge base allows the firm to respond in a more flexible way to various technological requirements and continencies (Zhang et al., 2007). Here, the RO view suggests that with a reduced technological uncertainty, taking an equity stake in a broad biotech firm would be more appealing to the large pharma partner: It will have the option to expand into attractive markets or technologies as well as the flexibility to contain downside risk by deferring further investment (Leiblein, 2003)

A biotech firm that is technologically broad, signals to the pharma partner because of its limited resources, it does not have the leverage to retain full ownership in an alliance. The uncertainty considerations on the pharma side makes the larger partner interested in purchasing equity:

> *H2.* The broader the technological resources of the biotech firm, the more likely it is to sell equity to the larger pharma partner when forming an alliance.

Lagoon firms are broader in their technological resources than both Pond and Gorge firms. Ocean firm are as broad as Lagoon firms, but breadth is not their main characteristic because they are also deep. With the same reasoning as for the previous hypothesis, we can expect Lagoon firms to be more likely to end up in equity-based alliances

H2.Complementary:

The Lagoon type of biotech firm is more likely to sell equity to the larger pharma partner when forming an alliance

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

Alliances are viewed as vehicles to acquire knowledge and learn new skills and the experience gained from prior collaborations may influence subsequent strategic decisions (Nielsen, 2005). Gaining from alliance experience, firms accumulate the capability to benefit from the interdependencies across diverse collaborative behaviors (Powell et al., 1996).

Biotechnology firms that have greater alliance experience learn to better negotiate and manage alliances with partners (Levitt and March, 1988). Since learning happens in a continuous and iterative fashion, 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 into a more formalized process, improving intra-organizational and inter-organizational routines and coordination (Hoang and Rothaermel, 2005).

A biotech firm's prior alliance experience is also a sign of its reliability and credibility (Gopalakrishnan et al., 2008; Gulati, 1995;) and it signals its access to other actors in the industry (Ahuja, 2000). The bargaining power of the biotechnology firm in alliance negotiations 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 et al., (2009) 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 the 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 partners may be more willing to trust the firm and enter into a non-equity agreement.

As argued before hypothesis 1, 'deeper' biotech firms leverage the depth of their technological resources as a sign of accumulated expertise over time. Now, with more alliance experience, they will enjoy an enhanced reputation for two reasons: First, they are technologically focused and their knowledge has evolved over time, and second, having had prior alliances implies greater credibility and reliability. A

'deep' biotech firm therefore enjoys even more bargaining power as it builds up more alliance experience. This leads to hypotheses 3a:

> *H3a.* 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.

With the same reasoning, we can expect Gorge firms with more alliance experience to be even less likely to engage in equity-based alliances:

H3a.Complementary:

> Gorge firms with more alliance experience are less likely to end up in equity-based alliances than those with less experience.

Prior alliance experience, even in the case of a technologically broad firm, implies that it has gained collaborative know-how: the ability to develop specialized knowledge and institutionalize 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 and Nielsen, 2009).

Similar to 'deep' firms, broad' biotech firms that were initially likely to sell part of their ownership in alliances, add to their technological resources as they acquire more alliance experience and leverage their credibility while negotiating alliance terms. This means they will depart from equity type of governance to non-equity, where they can keep full ownership of the technology in alliance:

> *H3b.* 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 weaker when the biotech firm has more prior alliance experience.

Similarly, we expect Lagoon firms with more alliance experience to less likely engage in equity-based alliances:

H3b.Complementary:

> Lagoon firms with more alliance experience are less likely to engage in equity-based alliances than those with less experience.

3. Research Methods

3.1. Research Design and Sample

To test the hypotheses of this study, we extracted and combined secondary data from three different sources: Recombinant Capital (ReCap) for alliance data, Derwent Innovation Index for information on patents and their underlying technology classes; and Compustat for firms' financial information. The 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.

In biopharma industry, patents play a central role in a firm's strategy as biotechnology appears to be a key competence for innovation in drug development (Zhang et al., 2007). Since a patent typically includes a description of a technical problem and a solution to that problem (Walker, 1995), patent data provide a consistent chronology of firms' knowledge accumulation (Shan et al., 1994).

Measures of depth and breadth of technological resources are constructed using information from the patents each biotech firm holds, as available in Derwent Innovation Index. To capture the role of technological resources of the biotechnology firm leading up to the alliance, we counted the number of patents in a three-year period: the two years leading up to and the year of the alliance. We also recorded the number of those patents which fall in a given technology class or subject area. Section 3.2 explains how these numbers are used to build measures of depth and breadth.

For alliance-level information, the ReCap database (Recombinant Capital) is used, 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, Compustat database is used 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.

3.2. Measures

Dependent Variable: Alliance governance structure $Gov(E, NE)$ is the dependent variable of this study. Alliances in the sample are categorized 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 sample.

It is important to clarify that, although equity-based relationships include both minority equity and joint venture agreements, but the latter form of partnership is excluded from this 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 Chakrabarti, 1996). Therefore, the focus here is on two broad categories of alliance structures: equity, (excluding joint ventures) and non-equity.

Independent Variables: Technology depth ($DEPTH$) and technology breadth ($BREADTH$) are the independent variables, both calculated at the alliance level. Following Zhang et al. (2007), depth is measured 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. It accounts for concentration of a firm in a given technology class relative to all firms in the industry. Then, the coefficient of variation for all the firm's RTA measures is calculated, as it follows:

$$\mathrm{depth} = \frac{\sigma_{\mathrm{RTA}}}{\mu_{\mathrm{RTA}}}$$

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)

Regarding 'technology classes' or 'subject areas', it is possible that a single patent falls in more than one area, for example in both "Chemistry" and "General & Internal Medicine". With the help of Derwent Innovation Index, a total of 123 technology classes were identified where firms had patenting activity in. The 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. Its measure is simple count of the total number of technology classes in which the firm was granted patents

(Zhang et al., 2007). From the total of 148 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 ($ALLYEXP$): The biotech firm's prior alliance experience is the moderating variable and is measured as the total number of alliances 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 controlled for other variables apart from technological depth and breadth that can have an impact:

Entry Stage of Technology Development ($STAGE$): Past research suggests that the bargaining power of the new technology firm increases with the development stage of the product candidate (Aghion and Tirole, 1994). Therefore, an important control variable in this 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. Following Gopalakrishnan et al. (2008) we consider 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 giving up equity ownership; or keeping its full ownership 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 (Dunne et al., 2009). 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 firm. The analysis here therefore accounts for the "size of the agreement relative to size of the biotech firm", operationalized 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 and the year of the alliance. We used a log transformation due to skewness and the large variability in this measure.

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

4. Analysis and Results

4.1. Results in the strategic groups

Figure 2 shows the scatterplot of the alliances in the 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, 11 observations with outlier 'breadth' values are removed. Then the remaining set of values for depth and breadth are split into groups of higher or lower than the average, to plot Figure 2. In fact, this figure corresponds to the earlier grouping of firms into 4 categories, namely: 1) Ocean, 2) Gorge, 3) Lagoon, and 4) Pond firms[3].

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Interestingly, the four subsamples substantiated our earlier expectations: First, firms that were both broad and deep were unlikely to need alliances. From a total of 390 alliances in our sample, only 13 involved "Ocean" biotech firms. Second, majority of alliances occurred with biotech firms that are labeled as "Gorge" (148 alliances) or "Lagoon" (86 alliances). This demonstrates that our hypotheses on depth and breadth of technological resources are relevant. There are, however, 132 alliances with "Pond" biotech firms.

The scatterplot in figure 2 brings even more evidence for the premise that most firms need to be either broad or deep in the focus of their technological resources. The arrows show the distribution of firms along the "merely deeper-merely broader" axis. Even when limiting ourselves to the subsample of

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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 as many biotech firms with the same values of depth and breadth entered to several alliances with different Pharma partners.

Lagoon or Pond firm, the premise still holds and biotech firms in alliances are inclined towards the two ends: either being broader or deeper than others.

A comparison among the four strategic groups also highlights interesting differences: The average Ocean firm is older than the average firm in any of the other three categories, consistent to the expectation that being both broad and deep means that the firm has taken many years to accumulate expertise and diversify into different fields. Also, alliances comprising 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 other three groups. Only 14 percent of alliances with Ocean firms included equity arrangements, while the number rises to 30 percent for Pond firms.

4.2.Results from testing the main hypotheses

Descriptive statistics and correlations for the relevant variables are displayed in Table 1. There exist high correlations between the main explanatory variables namely breadth, depth, and alliance experience. In order to assure that multicollinearity is not an issue, Value Inflation Factors (VIFs) are computed for each pair among the three variables. None of the VIF values reached 3, indicating that multicollinearity was not encountered.

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There is a strong negative correlation between technological depth and breadth, reinforcing the earlier assertion of this study that many firms need to invest exclusively in one of these two dimensions[4]. Among the control variables, stage and age are positively correlated, consistent with the notion that younger firms tend to enter into early stage alliances.

Here we present the results of testing the main hypotheses, and then in section 4.2 we will discuss the 'complementary' ones. Since the dependent variable, governance structure, is a dichotomous variable (equity versus non-equity), we used binary logistic regression as the method of analysis: Hierarchical

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[4] As George et. al (2008) put it, our concentration-based depth measure "penalizes firms for dispersion across patent classes", i.e. a broader firm gets lower depth values. While we recognize this, we still keep the measure this way because it compares the concentration of a firm's knowledge base with the concentration of other firms' knowledge bases, regardless of how the size of those knowledge bases compare. This relates to how we conceptualized depth: The relative focus that gives the focal firm more leverage than another firm lacking that focus but perhaps having more resources. Moreover, George et. al (2008) find a correlation of $r=0.80$, $p<0.001$ between their own depth measure and the concentration-based measure which is similar to ours.

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, four models are used, and the results of all regressions are illustrated in Table 2.

First the baseline model included only control variables; namely stage of technology, firm's age, firm's size, and relative size of agreement (model 1).

Then depth, breadth and prior alliance experience are added to get model 2 as below:

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

The above model is where hypotheses 1 and 2 are tested, 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 interaction terms $DEPTH \times ALLYEXP$ and $BREADTH \times ALLYEXP$ were inserted 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 equity to the pharmaceutical partner. Relative size of agreement also demonstrates a positive coefficient and significant in all the models, which implies that firms are willing to sell equity in return for more financial capital. Biotech firms in alliance face a trade-off between financial gain and ownership.

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Insert Table 2 around here

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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 equity in alliance through non-hierarchical arrangements. This supports hypothesis 1. The β coefficient corresponding to breadth is, however, not significant ($\beta = -0.04$). Therefore hypothesis 2 is not supported. The breadth of a firm's technological resources does not seem to impact the governance structure of the alliance. However, when only limiting the analysis to a specific strategic group, technological breadth had a significant impact on governance, as it will be

elaborated in section 4.3. The chi-square value for model 2, (Chi-square=7.51) was significant at the 0.05 level, meaning an improvement from the base model to model 2.

Model 3 included alliance experience as a moderator of the relationship between depth and type of governance. A significant negative relationship between interaction term $DEPTH \times ALLYEXP$ and equity type of governance is observed, lending support to hypothesis 3a ($\beta = -0.08, p < 0.05$). This means that, when they have more prior alliance experience, firms with deeper technological resources tend to engage even less in equity-based alliances. This interesting finding is discussed later in section 5. Moving from model 2 to model 3, an improvement in the goodness-of-fit is observed 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 hypothesized). Furthermore, 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 ($\beta = -0.29, p < 0.05$), the analysis finds that contrary to the expectation in hypothesis 3b, alliance experience combined with breadth led to more, not less hierarchical forms of governance. The 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 combined effect with alliance experience on the choice of governance.

4.3. Results from testing the complementary hypotheses

With the 'complementary' hypotheses, we wanted to test each of the four strategic groups relative to the others. In order to do so, we created dummy variables for each of the groups and ran the regressions in the overall sample. Our reference group was the Pond (low depth, low breadth) quadrant. The Ocean_dummy is dropped from the regressions because there were too few observations in this category and there was little variation among them. Therefore, we are left with Gorge and Lagoon dummies in the regression models. Being representative of the firms that are 'deeper than average' and 'broader than average', these dummies serve as our independent variables therefore we do not introduce DEPTH and BREADTH in the models. We still needed ALLIANCE EXPERIENCE and its interaction with each of the two dummies in order to check the moderating role of alliance experience in the relationships between firm groups and governance structure.

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Insert Table 3 around here

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The results are shown in Table 3. They are consistent with and fairly similar to our original results in Table 2, with some exceptions. Model 5 is the same base model as in the original regressions. Model 6 is where we introduce the dummies for Gorge and Lagoon as well as the variable ALLIANCE EXPERIENC. Results shows that the Gorge quadrant is negatively related to equity type of alliance governance ($\beta = -0.7, p < 0.05$), similar to the original results in model 2 where the depth dimension was negatively related to equity type of governance. This supports *H1.Complementary:* Gorge firms are more likely to engage in non-equity alliances. The dummy for the Lagoon quadrant is not statistically significant, similar the coefficient for breadth in model 2. Therefore, *H2.Complementary* is not supported. Alliance experience is significant ($\beta = -0.18, p < 0.01$) same as in model 2. Biotech firms with more alliance experience are more likely to end up in non-equity alliances.

Model 7: The interaction term 'Gorge_dummy x ALLIANCE EXPERIENCE' is negatively associated with equity governance mode ($\beta = -0.43, p < 0.05$), supporting *H3a.Complementary*. This is consistent with the original results in model 3 where the interaction term 'depth x alliance experience' was negatively related to equity type of governance

Model 8: The only difference from the original results was observed here, when we introduced the 'Lagoon_dummy x ALLIANCE EXPERIENCE' interaction term. This term shows a marginally significant and negative association with equity type of governance ($\beta = -0.18, p < 0.1$), lending partial support to *H3b.Complementary*. However, our original findings in model 4 had a significant positive coefficient for the interaction of breadth and alliance experience. We will discuss this inconsistency in section 5.

All in all, in three of the four models we found consistent results when using dummy variables for the quadrants instead of the original variables.

4.4. Results from testing the main hypotheses limited to each subsample

While the study tested the main hypotheses on the overall sample of firms, separate analysis were performed on each of the four strategic groups and the results are compared (the tables are not reported due to space limitations). This means that we repeated the same statistical analysis (models 1 to 4) in each subsample corresponding to each strategic group. Most noteworthy results were obtained from

analysis in Lagoon group (n=97) and Gorge group (n=148). Regression analysis in Pond (n=132) group did not yield any significant results to add anything new to our understanding from the overall sample. In Ocean (n=13) group the number of observations were too few to conduct any meaningful statistical analysis.

It is interesting to note that while in the overall sample we found no support for hypothesis 2 (technological breadth and type of governance), the breadth measure showed a significant positive association with equity type of governance when considering only the lagoon firms ($Table\ 3, \beta = 0.04\ , p < 0.05$.). It is also interesting to observe that in Gorge subsample the direction of this effect is reversed ($Table\ 3, \beta = -0.34\ , p < 0.05$) contrary to hypothesis 2. These interesting findings are discussed in section 5.

5. Discussion and Conclusions

Previous research has explained how knowledge and technological resources are important factors for the small technology firm's likelihood in retaining ownership in alliances (Dunne, Gopalakrishnan and 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 when partnering a larger firm. Moreover, the role of prior alliance experience is also explored.

Consistent with the first hypothesis, the findings confirm that the deeper a firm's technology and knowledge base, the less likely it is to form equity alliances. This is important because for a small firm, its knowledge or technology is a main resource involved in the alliance formation (Coombs and Deeds, 2000). The 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 complement the broad-based capabilities of the larger pharma partner. This finding could point to two facts: First, technologically-deeper biotech firms seem to be more appealing partners to the pharmaceutical firm, such that they can enjoy an improved bargaining position when negotiating alliance terms with the financier of their R&D projects. 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 goals of the project in an alliance.

The 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 et al., 2009), this study found that as the biotech firm accumulates more alliance experience, it is more capable of entering a non-equity alliance with the pharma partner (this was not formed as a hypotheses, since the interest of this study is not in the direct effect of alliance experience on governance, but in the interactive effects of the same with depth and breadth, respectively). Moreover, as hypothesized, the study found that technologically-deep biotech firms with more alliance experience, were better able to retain the equity rights in their downstream alliances, compared to those with less prior experience. The depth of technology signals capability of the biotech firm to its pharma partner, and the combination of depth with alliance experience (Srivastava and Laplume, 2014) leads to more trust and confidence from the larger pharma firm.

As to the impact of technological breadth on the type of governance, the analysis in the total sample did not yield any significant results. Furthermore, contrary to expectation, our findings showed that the biotech firm's alliance experience combined with breadth led to a greater engagement in equity-based partnership. While this is contrary to hypothesis 3b, the "complementary hypothesis 3b" was partially supported, implying that as Lagoon firms get more experienced, they might be less likely to end up in equity-based alliances.

The fact that alliance experience moderated the depth-governance and breadth-governance relationships in opposing ways, offers an avenue for further research. It could be that as they accrue more alliance experience, the broader firms become less concerned about opportunistic behavior from their pharma partners, and therefore may be more willing to give up equity. Many of the biotech firms in the sample had had previous ties with the same pharma partner. Therefore, our results demonstrate that the repeated ties lead the broad biotech firms to build more trust and sell equity to the larger partner. It could also be that broader firms recognize that they do not have the leverage like the deep firms to bargain for a non-equity alliance, and therefore, as they gain more alliance experience, they recognize that it is better to leverage the experience for financial capital. However, due to data limitation, the present research cannot confirm this. Further discussion is provided in section 5.2.

Finally, by performing the same regression analysis in each of the four strategic groups, we have some interesting results. While the expected positive association between technological breadth and equity type of governance was not found in the total population, the relationship was evident when limiting the analysis to Lagoon sub-sample, i.e. sample of 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 seemed to favor an equity-based governance structure. This could point to the

pharma firm's fear of opportunistic behavior by the Lagoon firms: the broader their resources, the more the potential to work on projects outside the scope of the alliance. It could also be that the Lagoon firms' need for funds pre-disposes them toward giving up equity and accepting the pharma firms' desired terms.

In the Gorge sub-sample, 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. its 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 ownership in alliance.

5.1. Contributions to the literature

This study sheds light on the knowledge characteristics of biotechnology firms and their impact on alliance governance structure. It highlights the importance of distinguishing between 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; Gopalakrishnan et al., 2008). Our paper adds to this research stream by suggesting that the depth and the breadth of technological resources can have a different impact in the alliance relationship (Srivastava and Laplume, 2014). 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.

Making the distinction between depth and breadth of technological knowledge can also help explain some contrarian findings in the bio-pharma alliance literature, 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. Stuart et al., 1999; Coombs et al., 2006; Gopalakrishnan et al., 2008).

The paper also contributed to our understanding of alliance governance forms by offering TCE and RO-based explanations. We argued that when extensive control rights are bestowed to the larger partner, TCE explains this party's concerns over opportunistic behavior. In the absence of such control rights specifically relinquished in the contract, we believe RO can explain why firms with deeper technological resources are more likely to end up in non-equity alliances. One might assume that when the pharma

partner acquires direct equity in the biotech firm, it is granted representation on the biotech firm's board (Pisano, 1989). However, in a detailed analysis of 125 alliance contracts, Robinson and Stuart (2007) show that only 15% of direct equity transactions specifically included board representation. This implies that many of the alliances in our sample might not have board representation either, and that is where we better rely on RO-based explanations rather than the "control rights" perspective offered by TCE[5].

Furthermore, this paper contributes to the literature on knowledge management by suggesting that research-intensive biotech firms behave differently based on their depth and breadth of knowledge. Firms in each group seem to have different challenges and opportunities as to how to benefit from and manage their knowledge resources.

5.2. Limitations and Future Lines of Research

Despite its contributions, this study has a number of limitations which offer avenues for future research: First, as the dependent variable was formed as a binary (equity versus non-equity alliance), it 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, the focus was solely 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 setting with more heterogeneity among the technology firms.

Third, the paper showed mixed 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, our study did not distinguish between repeated ties that a biotechnology firm forms with the same partner and those with a new one. By making this distinction, future research can explain the mixed findings regarding the moderating role of prior alliance experience. Considering that credibility and trust as mechanisms lead to less contractual complexity when firms ally, it means that repeated ties and new ties may have difference effects on the choice of governance structures.

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[5] We are grateful to the anonymous reviewer for their valuable comments that enriched this discussion

Fourth, while our focus was on the technological resources of the biotech firm as the main asset brought to the alliance, further research could also take into account the pharma firm's knowledge resources and investigate whether their depth and breadth can also play a role in alliance governance structure.

Finally, there seems to be a survivor-like bias in the sample. The firms in the sample are older and have had more previous alliances than the firms that are not included in the sample. This bias may mean that the results regarding the importance of prior alliance experience of the biotech firm may be somewhat inflated; it could be that the paper is not capturing a phenomenon regarding firms with less alliance experience. This bias may also explain the prevalence of non-equity arrangements in the sample.

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 (Moorthy and Polley, 2010). 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 this study, also helping the firm to keep equity rights in an alliance. 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 deciding on their knowledge strategy. With limited resources, small technology-based firms need decide on the type of technological knowledge that they should invest in: the one that brings them highest returns and greatest leverage in their inter-firm linkages.

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Table 1 (below): 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							
2. STAGE	0.35	0.72	0.06	1						
3.AGE	17.86	4.25	0.04	0.36**	1					
4. FIRM SIZE	4.42	1.08	-.28**	0.14**	0.12*	1				
5.AGREEMENT SIZE	12.07	12.82	0.27**	0.29**	-0.1	-0.12	1			
6. DEPTH	6.7	2.17	0.04	0.06	0.25**	-0.30**	0.07	1		
7. BREADTH	10.45	7.27	-.124*	0.02	-0.16**	0.36**	-0.02	-0.71**	1	
8. ALLIANCE EXPERIENCE	5.44	4.17	-.28**	-0.08	-0.05	0.52**	-0.15*	-0.28**	0.32**	1

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

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

Table 2 (below): Logistic Regression Models

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	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

Table 3 (below): Logistic Regression Models with Dummy Independent Variables

Dependent Variable	**Model 5**		**Model 6**		**Model 7**		**Model 8**	
GOVERNANCE (E=1, NE=0)	**Beta**	***s.e.***	**Beta**	***s.e.***	**Beta**	***s.e.***	**Beta**	***s.e.***
Constant	0.69	1.32	0.15	1.03	-0.42	1.07	0.3	1.04
Control variables								
STAGE	0.32	0.27	0.35	0.26	0.33	0.27	0.34	0.27
AGE	0.06	0.05	0.04	0.04	0.05	0.04	0.04	0.04
FIRM SIZE	-0.78***	0.21	-0.5*	0.19	-0.51**	0.2	-0.48*	0.2
AGREEMENT SIZE	0.1***	0.03	0.07**	0.02	0.07**	0.02	0.07**	0.02
Independent Variables								
Gorge_dummy			-0.7*	0.36	0.61	0.63	-0.76*	0.37
Lagoon_dummy			-0.27	0.42	-0.28	0.41	-1.07+	0.7
ALLIANCE EXPERIENCE			-0.18**	0.07	-0.08	0.07	-0.24**	0.08
Interactions								
Gorge_dummy x ALLIANCE EXPERIENCE					-0.43*	0.19		
Lagoon_dummy x ALLIANCE EXPERIENCE							-0.18+	0.12
Model								
Model Chi-square	46.06***		58.98***		66.05***		60.95***	
Pseudo R-squared	0.15		0.18		0.21		0.19	

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

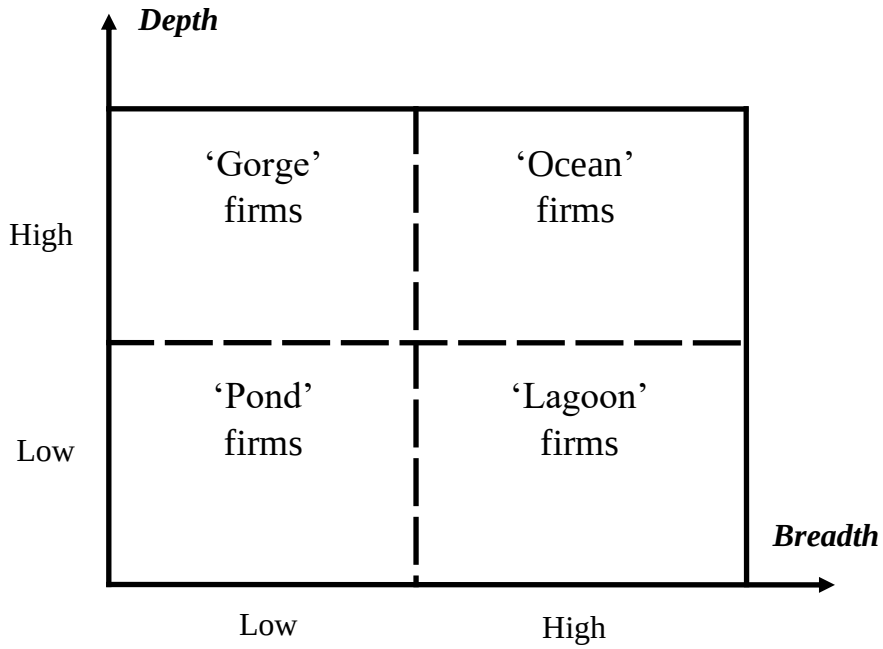

Figure 1: Biotech firms divided into four groups depending on the depth and the breadth of their technological resources

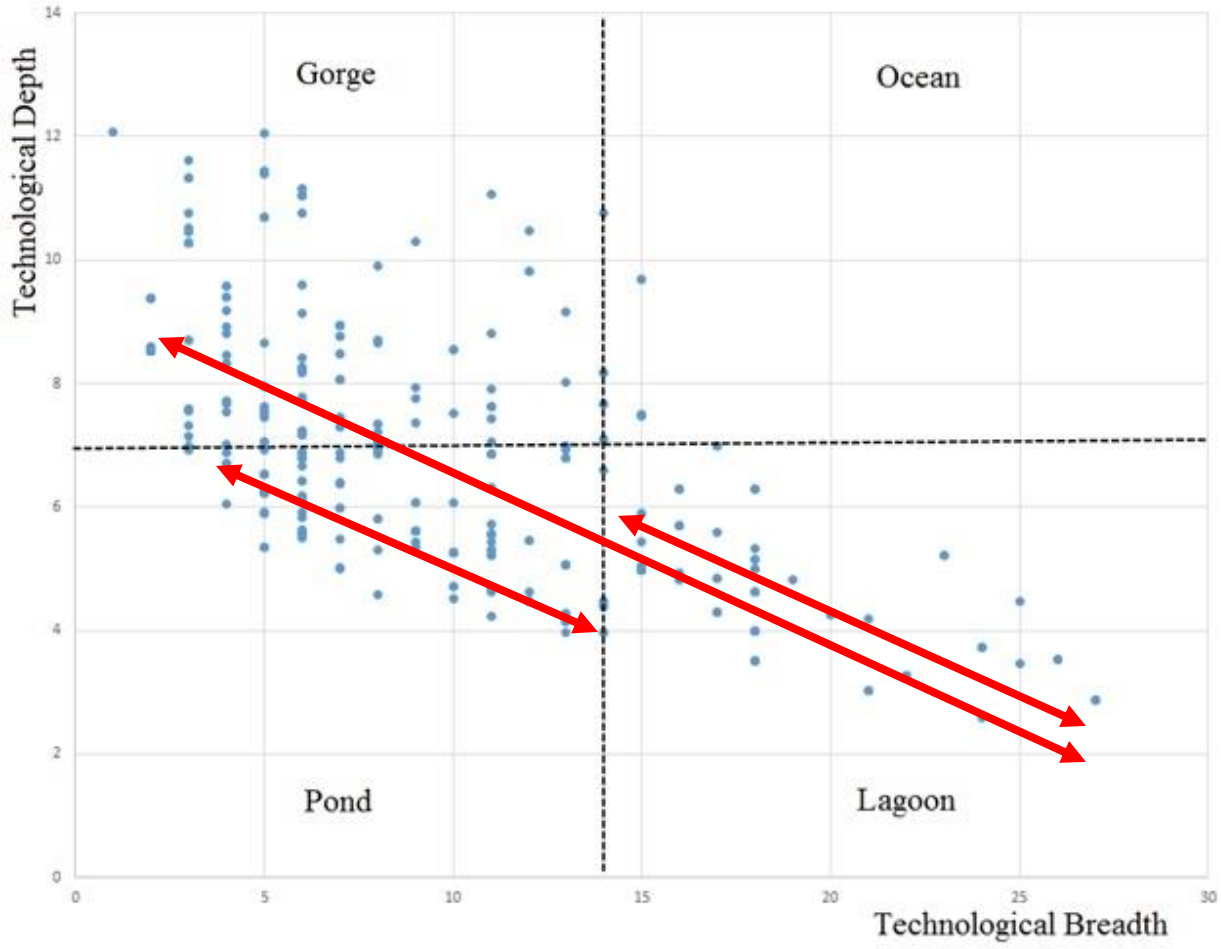

Figure 2: Scatterplot of all alliances in the sample, based on depth and breadth of the biotech partner's technological resources