The Effect of Contractual Complexity on Technology Sourcing Agreements

Hansen, Zeynep and Higgins, Matthew

Georgia Institute of Technology

17 September 2007

The Effect of Contractual Complexity on Technology Sourcing Agreements[*]

Zeynep K. Hansen
College of Business and Economics, Boise State University
1910 University Drive
Boise, ID 83725-1620
208.426.3314
zeynephansen@boisestate.edu

Matthew J. Higgins[**]
College of Management, Georgia Institute of Technology
800 West Peachtree Street
Atlanta, GA 30308
404.894.4368
matt.higgins@mgt.gatech.edu

13 September 2007

Abstract:

Most research on strategic alliances ignores the underlying contracts that govern the terms of the relationship. This is problematic since it is how these contracts are structured that determines *how* firms will benefit from a relationship. We present a novel method to analyze contractual complexity in a multi-dimensional framework in an attempt to link together the contractual complexity and control rights literatures. We find that the stage of development, age and prevalence of the underlying technology most influence complexity. Contractual complexity also influences the allocation of control rights. We also explore the importance of prior relationships on the underlying contract.

JEL Codes: G32, L22

Keywords: Contractual complexity; Control rights; Strategic alliances; Biopharmaceutical industry; Contractual design

[*] We thank Steven Currall, Stuart Graham, Frank Rothaermel, Michael Stonebrook, Tunji Adegbesan, Carolin Hausseler, Jackson Nickerson, Jerry Thursby and Leslie Vincent-Harris for helpful comments and suggestions. We thank Mark Edwards at Recombinant Capital for graciously providing access to their data. Finally, we are indebted to Dr. Beau Hansen for helping in the classification of the alliance technologies. Higgins acknowledges research support from the John Imlay Jr. Professorship and the Georgia Tech Center for International Business Education and Research under a national center grant from the U.S. Department of Education. Hansen acknowledges research support from Washington University in St. Louis, Olin School of Business during summer of 2007. Part of this research was completed while Hansen was at the Olin School of Business, Washington University, St. Louis, MO. The usual disclaimer applies.

[**] Corresponding author: Matthew J. Higgins, College of Management, Georgia Institute of Technology, 800 West Peachtree Street, Atlanta, GA 30308. matt.higgins@mgt.gatech.edu

1.0 Introduction

There exists an extensive literature, spanning multiple disciplines, focusing on strategic alliances. Researchers have explored, for example, why firms engage in alliances; how partners are chosen; what types of alliances are entered; how alliance portfolios are built; the impact on innovation and new product development; and whether alliances create value for shareholders. Often overlooked, however, in these literatures are the structure and influences of the underlying contracts that control these relationships. By overlooking these contracts, the complexity of the agreement and as a result, the complexity of the fundamental relationship is ignored. Furthermore, the structure of these contracts dictates the allocation of control rights which affect a multitude of items ranging from intellectual property rights to marketing, manufacturing and distribution. Research suggests that it is how these control rights are allocated determines how a firm will benefit from a research relationship (Adegbesan and Ricart, 2005).

Transaction Cost Economics (TCE) scholars argue that contracts will be more "complex" as more contractual safeguards are written into them in order to mitigate potential exchange hazards (Williamson, 1985, 1991). Likewise, when potential exchange hazards are low complex contracts are not needed and simpler, more routine ones are sufficient (Joskow, 1987). In addition to the complexity of the contract, the underlying provisions that deal with the actual allocation of specific control rights are also important since they determine how a firm benefits from the relationship. While several papers have directly studied the allocation of control rights (Lerner *et al*, 2003; Lerner and Merges, 1998; Elfenbein and Lerner, 2003; Lerner and Malmendier, 2004; Higgins, 2007; Adegbesan and Higgins, 2007) we are not aware of any research that explores the direct relationship between contractual complexity and the allocation of control rights in technology sourcing agreements. We attempt to fill this important gap by bridging together these two literatures through the analysis of strategic alliance agreements between pharmaceutical and biotechnology firms.

We make several contributions to the literature. First, we extend the literature on contractual complexity by modeling complexity in a multi-dimensional framework. This framework allows us to focus on both the functional scope and the technological scope of

an agreement. Functional scope provides us with a measure of the *breadth* of an alliance while technological scope provides us with a measure of the *depth* of an alliance. We measure functional scope based on specific contractual provisions, which is not uncommon in the literature (e.g., Ryall and Sampson, 2006; Reuer and Arino, 2007). However, in order to measure technological scope we explicitly control for and model the underlying focal technology(s) in the alliance relationship.

Second, within our framework, we analyze the determinants that increase the probability that an alliance agreement will be more complex. One of the most significant factors that increase the complexity of an agreement is the phase of the focal product at the time of signing. Alliances whose focal products are in later stages of development tend to focus on one technology and this simplicity is reflected in the underlying contract structure. Additionally, the age *and* prevalence of the focal technology are important. The newest technologies and ones that are the least prevalent in the population of alliances increase the probability of more complex agreements. New and less prevalent technologies can be viewed as more risky and as a result more complex agreements are written to protect the parties.

Third, we tie the contractual complexity literature to the control rights literature by analyzing the relationship between contract structure and the allocation Of control rights. All of the extant literature focusing on control rights ignores the underlying structure of the actual agreement.[1] In addition, we follow Higgins (2007) and control for the relative bargaining position of both the pharmaceutical and biotechnology firm. We find that of the two dimensions of contractual complexity we propose, functional scope has a negative and significant impact on the number of rights allocated to the pharmaceutical firm. We argue that this suggests pharmaceutical companies are able to "bargain" or "trade" some sets of control rights for other sets of rights.

Fourth, we find that as a firm's stock of alliances increases or if they have had prior relationships with a partner contracts tend, on average, to be less complex. This finding contrasts with Ryall and Sampson (2006) who find that contracts are more detailed when firms have prior relationships. However, Ciccotello and Hornyak (2000),

[1] See, for example, Lerner *et al*, 2003; Lerner and Merges, 1998; Elfenbein and Lerner, 2003; Lerner and Malmendier, 2004; Higgins, 2007; Adegbesan and Higgins, 2007.

Parke (1993) and Gulati (1995) find some evidence of reduced contractual safeguards between firms engaging in repeated contacts. They attribute their findings to increased levels of trust. Indeed, there is a literature dealing with relational norms, such as trust, that view these types of activities as substitutes for complex contractual agreements (Granovetter, 1985; Bernheim and Whinston, 1998; Bradach and Eccles, 1989; Dyer and Singh, 1998; Gulati, 1995; Uzzi, 1997; Adler, 2001).[2] Our focus on the biopharmaceutical industry makes these findings even more interesting given average product development cycles of 10 to 15 years (DiMasi, 2001). Given this time frame, the risk and uncertainty involved, along with potential significant payoffs, one might expect to see more complex agreements in order for firms to protect themselves, however, we see the opposite.

The remainder of the paper is organized as follows. Section 2 discusses our framework for contractual complexity and control rights; Section 3 discusses our data and sample construction; Section 4 presents and discusses our empirical finding; Section 5 discusses and presents robustness results; and, Section 6 summarizes the analysis and discusses the next evolution of this research.

2.0 Contractual complexity and the allocation of control rights

Transaction Cost Economics (TCE) scholars generally define "contractual complexity" in terms of the increased number of contractual safeguards written into contracts in order to mitigate potential exchange hazards. Broadly, three types of exchange hazards are defined that necessitate the need for contractual complexity: asset specificity, measurement difficulty and errors, and uncertainty (Williamson, 1985, 1991). Uncertainty is considered as an exchange hazard specifically when asset specificity is present in a relationship. According to TCE theory, more contractual safeguards will be needed as the risk of opportunistic behavior increases due to one or more of these exchange hazards. In contrast, when the likelihood of exchange hazards is low, the associated costs of complex contracts are not necessary and relatively simple ones are

[2] Poppo and Zenger (2002) extend this literature by arguing that relational norms can be viewed as complements to complex contractual arraignments. In a recent research, Gulati and Nickerson (2007) find evidence that preexisting inter-organizational trust increases the probability of choosing a less formal and less costly mode to relationships.

sufficient (Joskow, 1987). Several empirical studies support these predicted relationships (Joskow, 1988; Pisano, 1989; Oxley, 1997).[3]

The extant empirical research on strategic alliances which focuses on contractual safeguards within TCE generally address the question of when or under what circumstances firms choose one type of alliance over another. This type of research usually puts alliances into broad categories (such as non-equity vs. equity; and, alliance or acquisition activity) and finds that a higher likelihood of exchange hazards results in more hierarchical contractual agreements since these agreements provide more control and shared ownership (Oxley, 1997; Sampson, 2004). Many of the studies which focus on the contractual complexity of alliance agreements overlook the underlying provisions that are included in contracts.[4]

In addition, analyzing the complexity of contracts alone ignores the underlying allocation of specific control rights. It is the underlying allocation of these rights, regardless of the complexity of the contract that will help determine how a firm will benefit from the research relationship. For example, Adegbesan and Ricart (2005) find that innovation might not significantly improve a firm's performance if value is asymmetrically appropriated by one of the parties to the agreement. Notwithstanding prior contributions there exists no research that explores the direct relationship between contractual complexity and the underlying allocation of control rights in an alliance or technology sourcing agreement.

2.1 Contractual complexity

The notion of contractual complexity has been studied elsewhere in the literature (e.g., Reuer and Arino, 2007; Robinson and Stuart, 2007; Barthelemy and Quelin, 2006; Ryall and Sampson, 2006; Oxley and Sampson, 2004; Luo, 2002; and, Poppo and Zenger, 2002; Joskow, 1988). However, these studies differ widely in their approach and

[3] A competing literature dealing with relational norms, such as trust, views these types of activities as substitutes for complex contractual agreements (Granovetter, 1985; Bernheim and Whinston, 1998; Bradach and Eccles, 1989; Dyer and Singh, 1998; Gulati, 1995; Uzzi, 1997; Adler, 2001. Poppo and Zenger (2002) contribute to this stream of literature by arguing that relational governance act as complements and not substitutes to complex contractual relationships. We will directly address this stream of research throughout our paper.

[4] A notable exception is Reuer and Arino (2007).

definition of complexity. For example, some use broad measures such as contract length or number of provisions (Robinson and Stuart, 2007; Joskow, 1988) and others focus on inclusion or exclusion of specific provisions (Barthelemy and Quelin, 2006). Barthelemy and Quelin (2006) examine the link between three types of asset specificity and contractual complexity. They define contractual complexity by the extent to which contracts are comprised of "elaborate clauses".[5] Ryall and Sampson (2006) examine telecommunication alliance contracts and find that prior alliances, in general and with a specific partner, have an effect on contractual structure. Contractual completeness in their study refers "…to the degree to which required inputs, expected outputs and division of intellectual property rights are fully specified" (p.12, 2003). Poppo and Zenger (2002) focus on the complementary relationship between formal contacts and relational governance. Their focus is on the information systems industry and contractual complexity is defined based on a survey asking about the customization and extent of legal work the contracts required.[6] In a more recent study, Reuer and Arino (2007) examine the determinants and dimensions of contractual complexity focusing on weighted and un-weighted measures of eight classes of contractual safeguard provisions originally developed in a study by Parkhe (1993). They include "enforcement provisions" such as confidentiality, termination, arbitration and lawsuit clauses and "coordination provisions" such as notification and auditing rights.[7]

In contrast to this body of work, we define contractual complexity along a multidimensional framework: functional scope and technological scope. Functional scope provides us with a measure of the *breadth* of an alliance contract while technological scope provides us with a measure of the *depth* of an alliance contract. We argue that our multidimensional focus on complexity is a better way to measure contractual complexity in technology sourcing agreements. Broad measures such as

[5] Where "elaborate clauses" are comprised across different types of clauses including control, incentive, price, evolution, and end of contract.

[6] Poppo and Zenger (2002) is a pivotal study in the stream of research dealing with relational governance. Prior work (including Granovetter, 1985; Bernheim and Whinston, 1998; Bradach and Eccles, 1989; Dyer and Singh, 1998; Gulati, 1995; Uzzi, 1997; Adler, 2001) focused on substitutability between relations and complex contracts. Poppo and Zenger (2002) argue that these types of relationships are in fact complementary with complex contracts as opposed to substitutes.

[7] Similarly, Lerner and Malmendier (2004) study the allocation of termination and exit rights and their use in helping firms mitigate moral hazard issues.

contract length and the number of provisions included in a contract do not consistently define contractual complexity across heterogeneous contractual relationships and focusing only on certain provisions may be too limited and ignore other relevant aspects of contractual design (Reuer and Arino, 2007). Our definition of contractual complexity (discussed in more detail in Section 3.2), on the other hand, is a measure of the activities and technologies chosen to be included in an alliance, which is subsequently then specified in a contract. More specifically, functional scope identifies the extent of value chain activities, such as manufacturing, marketing and distribution that alliance partners choose to include in technology sourcing agreements. This measure of the *breadth* of technology sourcing agreement is similar to the alliance scope definition in Oxley and Sampson (2004).[8]

Another dimension of the scope of an alliance is the level of technological complexity. Technological complexity, especially in research-intensive alliances, is particularly relevant since it relates to firm capabilities and the overall uncertainty of the focal projects. We argue that in technology sourcing agreements another dimension of contractual complexity is based on technology scope. Technology scope or the number of technologies that are specified in an alliance defines the *depth* dimension of contractual complexity.[9] [10] The greater the scope of an alliance is in either dimension, the more interdependent and extensive it will be. As a result, an increase in either the *breadth* or *depth* of an alliance will increase the expected collaborative intricacy of the relationship and thus contractual complexity.

When a project is more complex and a greater number of alliance activities are jointly completed, then TCE predicts that the risk for exchange hazards, such as potential opportunistic behavior and leakage of knowledge, may be greater (Williamson, 1985,

---

[8] Heiman and Nickerson (2004) study the tension between the need to share knowledge and the need to safeguard against uncontracted for expropriation of knowledge. In analyzing publicly announced alliances from 1977 to 1989 they construct a measure of tacit knowledge that is similar to our notion of breadth.

[9] Theoretical conceptualization of technology scope (Khanna, 1998 and Khanna, Gulati and Nohria, 1998) and empirical analysis by Oxley and Sampson (2004) acknowledge that alliance scope is a multidimensional measure but to our knowledge this is the first empirical paper to construct such a multidimensional measure.

[10] Oxley and Sampson (2004) argue that functional scope is a "vertical" scope measure and "horizontal" activities, which they do not include in their analysis, are related to uncertainty and complexity of the alliance project. In our definition, technology scope, which defines the technological complexity of a project, is a depth or a vertical measure.

1991). Prior research mainly focusing on the governance choice decision, demonstrates that hierarchical governance forms (e.g., equity joint venture) are more likely to be adopted when the alliance scope is greater. Alliance scope in these studies is determined by the inclusion of functional activities or the number of projects involved in an alliance (Pisano, 1989; Oxley, 1997). An important exception to this is the research by Oxley and Sampson (2004) where the determinants of alliance scope are explicitly analyzed.

In the extant literature the concepts of complexity and uncertainty are often used interchangeably. This creates problems in the empirical examination of the effects of uncertainty on the governance modes of transactional relationships (Slater and Spencer, 2000).[11] In our analysis, we specifically examine how technology characteristics, which define the level of technological uncertainty in an R&D agreement, affect the *depth* of alliance scope and thus contractual complexity. In collaborative R&D alliances, contract specification is difficult since technological know-how is highly tacit (Mowery and Rosenberg, 1989). For newer and less known technologies, contract specification is expected to be even more challenging than those alliances with older, more established technologies since the level of tacitness in technological know-how is greater (Davidson and McFetridge, 1984). To facilitate R&D collaboration and increase the effectiveness of technological communication, partner companies may choose to technologically broaden the scope of an alliance to include other related technologies in addition to the novel technology or the novel aspect of technology that is of main interest. Thus, companies that chose to engage in projects using highly uncertain and novel technologies may also chose to increase the *depth* or the technological detail of their R&D collaboration. Similarly, those technologies that are either new or old but less prevalently used are also

[11] The treatment of uncertainty in empirical research is not consistent for other reasons as well. Most importantly, there are many different types of uncertainty. Primary uncertainty is about the lack of knowledge about the state of nature and it includes some constructs of environmental uncertainty such as regulatory changes and technological uncertainty. Secondary uncertainty is about the lack of understanding of other economic agents and generally arises from lack of communication or the inability to assess other party's plans and actions. Behavioral uncertainty, as defined by (Williamson (1975, 1981), arises from strategic actions of contracting parties such as deliberate non-disclosure or purposeful misrepresentation. Another explanation for the ambiguity in empirical examination of uncertainty is that the TCE prediction of more hierarchical governance under uncertainty only holds when relationship specific investment or asset specificity is present in a contractual relationship (Klein, 1990). Since our analysis includes R&D alliances, we contend that relationship specific investment is present in every contractual agreement in our dataset. In addition, we are very careful in defining technological complexity and technological uncertainty in our analysis.

likely to be more uncertain, and thus require technologically deeper, more detailed contracts.

2.2 Allocation of control rights

In addition to analyzing the *breadth* and *depth* of a contract we go one step further and delve into the actual contracts to study the allocation of control rights and the relationship between that allocation and complexity. Regardless of how the underlying contracts are structured and what terms are included, it is how the individual rights are allocated that will determine how a party will benefit from the agreement. We address this issue next.

Since the seminal work of Coase (1937), economic research has considered the boundaries of the firm. Grossman and Hart (1986) and Hart and Moore (1988) consider the issue of incomplete contracting between principal and agent. Here two parties are unable to draft a contract that is capable of covering all potential contingencies that may arise during their relationship. As a result, they suggest optimal ownership of a project should be assigned to the party with the greatest marginal ability to impact the final outcome. This party should be the one who retains the right to make decisions not explicitly specified by contract. Consequently, they should also be the firm that receives any and all of the surplus rents generated by a given project. This allocation of rights should provide an incentive to the firm to function in a manner which will optimize returns from the project and, in turn, maximize their own potential surplus.

Aghion and Tirole (1994) utilize the Grossman-Hart framework to model a research and development alliance between two firms. They begin by assuming that research-intensive firms are without financial resources of their own and are restricted from being able to borrow money or commercialize their own innovations. As a consequence, the research-intensive firm will turn to a "customer" for alliance financing. The "customer" in this framework is the party who will directly benefit from the innovation. The customer is assumed to be unable to independently develop the research-intensive firm's innovation. Aghion and Tirole posit that the bargaining position of the

two firms will have an impact on the subsequent allocation of control rights for the innovation.

Lerner and Merges (1998), Lerner *et al* (2003), Higgins (2007) and Adegbesan and Higgins (2007) empirically test the above theoretical prescriptions by exploring the role that the availability of public financing has on the bargaining power of the research-intensive firm and the subsequent allocation of control rights. Aghion and Tirole (1994) do not explicitly discuss the role of public financing. However, Lerner *et al* (2003), claim "…it is reasonable to believe that variations in the availability of public financing will affect the bargaining power of R&D firms." This is supported by Aghion and Bolton (1992) and Holmstrom and Tirole (1997) who find strong links between the transfer of control rights and the conditions of public equity markets, in terms of the availability of public financing.

Within the framework of Aghion and Tirole (1994), Lerner and Merges (1998) find that the number of control rights allocated to the biotechnology firm is an increasing function of both the firm's financial health and the presence of favorable conditions in the marketplace. Biotechnology firms with more revenues in the year prior to the alliance agreement were less likely to negotiate away their control rights. The presence of revenues serves as an indication that the firm was negotiating from a position of relative strength. This finding is consistent with prior theoretical predictions.

Lerner *et al* (2003) and Higgins (2007) explore whether alliance financing agreements provide for different allocation of control rights between periods of varying availability of public financing. Theory suggests that agreements signed in periods with limited availability of external financing will be less likely to maximize innovative output. Lerner *et al* (2003) and Higgins (2007) find that in periods of limited availability of public financing, smaller biotechnology firms seek out larger pharmaceutical firms for alliance financing. In these agreements, biotechnology firms are in fact more likely to cede a greater number of control rights to the financing (pharmaceutical) firm.

Dessein (2005) develops a theory of the structure of alliances between an investor firm and an entrepreneur. His model is based upon asymmetric information driving the main underlying motivation behind the allocation of control rights. He finds that even a small amount of asymmetric information will cause the entrepreneur to relinquish a

substantial amount of control to the investor in an effort to signal his congruence. He also finds that the relinquishing of control is an increasing function of the level of informational asymmetries and a decreasing function in the resources of the entrepreneur. This result implies that early stage projects, where the information asymmetries are the largest, will be where the most rights are given up. While this finding is consistent with Lerner and Merges (1998), it is inconsistent with prior theoretical predictions.

Aghion and Tirole (1994) consider the bargaining positions of both firms, while the empirical work by Lerner *et al* (1998, 2003) focuses on the bargaining position of the smaller research-intensive firm, in terms of their ability to access public equity markets. These studies allow the overall health of the larger customer firm to remain fairly static.[12] As a result, the bargaining position of the customer firm is excluded from the analysis. On the other hand, Elfenbein and Lerner (2003), Higgins (2007) and Adegbesan and Higgins (2007) endeavor to account for the bargaining position of *both* firms. While bargaining position of the two firms is measured slightly differently across these studies, all three of these studies find evidence that the allocation control rights studied are sensitive to the underlying relative bargaining position of the two parties.

The impact of contractual complexity, however defined, on the underlying allocation of control rights has not been addressed in the literature. Our study sets out to fill this gap in the literature. Not only do we extend the contractual complexity literature by analyzing complexity within a multidimensional framework but we also study whether this complexity matters for the allocation of control rights. Control rights clearly matter to firms. It is how these rights are allocated that will dictate how, for example, the firm will benefit from future financial rewards (Adegbasen and Higgins, 2007). Moreover, the use of control rights can be used to help mitigate moral hazard issues inherent in these types of agreements (Lerner and Malemendier, 2003). The interplay between contractual complexity and control rights will tell us whether firms are able to gain (or lose) by entering more (or less) complex agreements.

[12] These studies also implicitly assume that the smaller biotechnology firm is captive to one customer. However, on average, from 1994 to 2001, biotechnology firms had, on average, six alliance partnerships with other large pharmaceutical companies. This would seem to suggest that a large pharmaceutical partner should be unable to demand excessive rents or control rights for fear that the biotechnology firm would seek out another partner. In the above referenced works, the pharmaceutical firm or customer is assumed to be unable to independently develop the innovation in question. The loss of such a technological innovation could place the pharmaceutical firm at a competitive disadvantage.

3.0 Data and sample

We study technology sourcing agreements (alliances) between biotechnology firms and larger pharmaceutical manufacturers. Data for this paper is drawn from multiple sources including Recombinant Capital (rDNA and ReCapRx), BioScan, FDA Orange Book, IMS Health, Thomson Derwent, NDA Pipeline, Pharmaprojects and Compustat.

3.1 Alliances and determination of control rights

Alliance information is obtained from Recombinant Capital, a California-based biotechnology consulting firm. Their data identifies alliances in the biopharmaceutical industry from 1973 up to the present. It provides both a general description as to the nature of the alliance along with detailed analyses of some of the actual alliance contracts. From this data we randomly selected 240 alliances involving just two parties (a pharmaceutical and biotechnology firm), whose main focus is on research and development and has a detailed contract analysis available. We restrict our sample to alliances involving just two firms in order to be able to clearly identify the allocation of control rights.

Not every alliance identified in the Recombinant Capital database has a detailed contract analysis associated with it. The choice of which contracts to analyze by Recombinant Capital *may* not be a random phenomenon. The non-randomness of this choice may very well introduce a selection bias into the sample; however the direction and magnitude of a potential bias remains unclear. As a result, the potential presence of underlying variables which could strongly impact the chance for inclusion into the analysis process warrants the use of a Heckman selection model (Greene, 2003). The dependent variable in the regression equation is *Total rights*, the total number of control rights allocated to the pharmaceutical firm. The independent variables for the regression equation are the same as those that will be used in subsequent analyses and will be discussed below. In no cases are any of the selection equation variables significant at

least at the 10% level. Moreover, in every case the reported χ^2 test, which is equivalent to testing for ρ =0 (where ρ is the correlation between the error terms of the regression and selection equations), is not significantly different from zero. As a result, since ρ is not significantly different from zero, standard regression techniques can be applied to the regression equation without concern of introducing a selectivity bias.

Consistent with Lerner *et al* (2003) and Higgins (2007) and in order to avoid unnecessary heterogeneity, transactions are excluded where:

- One of the parties is a government agency or university.
- The current alliance is a renegotiation or restatement of a previous alliance between the two firms.
- There exists no research component or aspect to the alliance.
- One firm has a controlling interest in the other firm (greater than 50%).

Each contract is reviewed for relevant deal information including: the date of the alliance, the technology and subject covered, total value of the agreement, up-front payments, royalty rates, equity stakes, contingent or milestone payments, and stage of the lead product. Table 1 presents a description of the variables while Table 2 summarizes this information. Correlations for all variables are presented in Table 3. The average size of the alliances in our sample is approximately $58 million (all values are in constant 1999 dollars). Upfront payments are present in 83 percent of the deals and average $7.91 million. The median upfront payment is $5.3 million. Running royalty payments are identified in 44 percent of contracts and average 24 percent of net sales. The median running royalty is 15 percent of net sales. Milestone payments of some type are present in 54 percent of agreements. For the milestone contract terms that are available, for products at these early stages, long-term financial rewards are very significant. Unfortunately, the probability that a product makes it from pre-clinical testing all the way to approval is very small, so the odds are against the biotechnology firm collecting on the full value of the milestone payments.

Contracts are also reviewed in order to determine the allocation of control rights. There are a broad spectrum of control rights that can be considered ranging from corporate governance, alteration in the scope of the alliance, control of technologies,

disposition of patented and unpatented information and the control of clinical trials and subsequent manufacturing and marketing of developed products.

Since we are concerned with research and development activities, we want to come up with a subset of control right rights that directly influence the R&D relationship between the pharmaceutical and biotechnology firms. After consulting with representatives in the biotechnology and pharmaceutical industries, the following bundle of eight control rights are selected to be included. Each of these eight rights is further sub-categorized for analysis purposes. Three sub-categories are used: intellectual property rights, exit strategy, and license.

Intellectual Property Rights

1. Ownership of patents;
2. Control and responsibility for patent litigation process;
3. Transfer of unpatented R&D "know-how";

Licensing Rights

4. Right to sub-license;
5. Royalty payment tie-ins;

Exit Rights

6. Product reversion rights upon termination; and,
7. Changes in control;
8. Right to terminate without cause.

A forth sub-set of two additional rights were also collected for the purposes of identifying the functional scope of the contract (discussed in detail below).

Manufacturing & Marketing Rights

9. Control of initial manufacturing process;
10. Marketing rights to the product;

It should be noted that there are a broad spectrum of control rights that can be considered when analyzing alliance biopharmaceutical agreements. The rights analyzed

in this paper are slightly different than the rights considered in Lerner *et al* (2003), Higgins (2007) and Adegbesan and Higgins (2007). The differences in rights selection across these projects mainly revolves around the issues being studied. For example, the bundle of rights utilized in Adegbesan and Higgins (2007) focus solely on those rights that influence the split of the future "financial pie". Higgins (2007) showed general robustness to Lerner *et al*'s (2003) bundle of rights for the specifications being tested. Our specific selection of rights generally follows Higgins (2007) and will be discussed more fully below.[13]

3.2 Contractual complexity

For the purposes of this paper we will define contractual complexity along two separate dimensions: functional scope and technological scope. Functional scope will provide us with a measure of the *breadth* of an alliance contract while technological scope provides us with a measure of the *depth* of an alliance contract. Fig. 1 presents our notion of contractual complexity in a 2 x 2 matrix. We further divide functional and technological scope into *low* and *high* types. Technological scope is deemed *low* if the alliance agreement focuses on only one technology. In contrast, technological scope is deemed *high* if the alliance agreement focuses on more than one technology. Obviously, the larger number of technologies covered, the greater the internal capabilities of the two firms need to be – especially for the biotechnology firm. We define *Technological scope* as a dummy variable that equals one if the alliance contract covers more than one technology. 33 percent of the sample contracts fit in the *high* category.

Functional scope is deemed to be *low* if the alliance agreement focuses solely on research and development and contains only focal rights described in Section 3.1. In contrast, functional scope is deemed to be *high* if the alliance agreement includes provisions dealing with marketing, manufacturing and distribution. We therefore define *Functional scope* as a dummy variable that equals one if an alliance contract contains

[13] As a robustness check Higgins (2007) uses the same selection of rights as Lerner *et al* (2003). The results were qualitatively consistent.

marketing, manufacturing or distribution provisions. 30 percent of the sample contracts fit in the *high* category.

Referring to Fig.1, an alliance contract in the top left quadrant (L, L) is one that focuses only on one technology and contains no provisions with respect to marketing, manufacturing and distribution. In contrast, an alliance contract in the lower right quadrant (H, H) is one that focuses on more than one technology and contains provisions for marketing, manufacturing or distribution. For the overall sample, 42 percent of the alliance contracts fall into the (L, L) quadrant, 25 percent fall into the (H, L) quadrant; 28 percent fall into the (L, H) quadrant and 5 percent fall into the (H, H) quadrant.

We combine these two dimensions to construct a continuum for measuring overall contract complexity. We categorize contracts in the following order from simple to complex: (L, L), (H, L), (L, H), and (H, H). That is we define the simplest contract (L, L) as one that does not include marketing, manufacturing or distribution provisions (*Functional scope* equals "L") and covers only one technology (*Technological scope* equals "L"). In contrast, we define the most complex contract (H, H) as one that includes marketing, manufacturing or distribution provisions (*Functional scope* equals "H") and covers more than one technology (*Technological scope* equal "H").

By reformatting the quadrants represented in Fig. 1 into a linear continuum we need to decide whether to order (H, L) and (L, H) in this manner or (L, H) and (H, L). After consulting with representatives responsible for negotiating alliance contracts from both the pharmaceutical and biotechnology industry, we use the former, (H, L) and (L, H). There was general agreement that alliances covering more than one underlying technology made the overall alliance more complex than an expanded functional scope.

We define *Complex I* as a categorical variable from one to four for our four categories of contractual complexity. (L, L) is assigned one while (H, H) is assigned a value of four. *Complex I* has a mean (median) value of 1.96 (2.00) and a standard deviation of 0.95. Given that our conversations with industry representatives seemed to indicate that technological scope may be more influential on complexity than functional scope, we define *Complex II* as a dummy variable that equals one if *Complex I* equals three (L, H) or four (H, H). *Complex II* will be used for robustness purposes.

3.3 Technology age and prevalence

From Recombinant Capital we are able to identify the focal technology(s) underlying each alliance. As a result we are able to determine both the age of the focal technology and its prevalence. For our purposes, age is a function of when a focal technology is first identified in any alliance.[14] It is certainly the case that focal technologies may exist before their first appearance in an alliance – either physically or conceptually. However in most cases detecting this type of information in a consistent manner is not possible. By focusing on the appearance of a technology in a first alliance we are using a homogenous standard across all technologies. We define *Technology age* as a dummy variable that equals one if the difference between the year of the contract and year of first appearance in the population of alliances for the focal technology is less than or equal to five years.[15] The mean value for *Technology age* is 0.22 which implies that 22 percent of the focal technologies are less than or equal to five years of age.

Just because a technology is old does not necessarily imply that it is prevalent or has diffused into the industry. We attempt to capture how prevalent a focal technology is by counting the number of other alliances that used the focal technology until the date of the sample alliance. As such, we define *Technology count* as the number of alliances in the population of Recombinant Capital's database within the focal technology that have been initiated until the sample alliance. The mean (median) number of prior alliances in the population utilizing the same sample focal technology is 214.34 (120). The simple correlation between *Technology count* and *Max Years Since* is 0.5483. This suggests that while there is a positive correlation, simple age is not the only driving factor of a technology's prevalence.

3.4 Pharmaceutical research pipeline

[14] We utilize Recombinant Capital's database and limit the lower end at 1980. This constraint is imposed due to data limitations in other data sources, namely the pipeline data. Moreover, the industry itself was fairly new at this point, with the first round of large scale firms going IPO in the mid 1980s.

[15] As a robustness check we define a more basic variable *Max Years Since* to be the difference between the year of the contract and the year of the first alliance in the population of alliances for the focal technology. Results were qualitatively consistent. The mean (median) age of our focal technologies are 10.20 (9) years with a standard deviation of 4.96.

We follow Higgins and Rodriguez (2006) and Higgins (2007) and construct a weighted-value of each pharmaceutical firm's pipeline products using data from NDA Pipeline, Pharmaprojects and supplemented from ReCapRx from 1989 to 2001. This measure is referred to as the *Score*. A relatively high *Score* indicates a healthy product pipeline versus a company with a lower value *Score*. A declining *Score* in the years prior to an alliance indicates a company whose product pipeline is deteriorating. Firms in this situation negotiate and bargain from a position of weakness. Conversely, an increasing *Score* value in the years prior to an alliance would indicate that a company's product pipeline is expanding and therefore they can bargain from a position of strength (Higgins, 2007).

3.5 Financial data

Financial data for both the pharmaceutical and biotechnology firms is summarized in Table 2 and is obtained primarily from Compustat. Some financial data is supplemented from individual firm's filings and corporate internet sites. Biotechnology initial public offering (IPO) data is obtained from Securities Data Corporation (SDC). Pharmaceutical firm external R&D data is collected from Recombinant Capital.

4.0 Empirical findings

4.1 Technological scope

Table 4 presents probit estimates for our data regressing *Technology scope* on a series of independent variables expected to affect the probability that a pharmaceutical firm enters a technologically complex agreement.[16] The dependent variable used in the regressions reported in Table 4 is an indicator variable $y_{it,}$ that assumes a value of one for a given firm *i* in a specific year *t* if that firm enters into an alliance that contains more than one underlying technology, and is zero otherwise.

For independent variables we use a weighted measure of the pharmaceutical firm's research pipeline in the year prior to the alliance (*Score*); the natural log of pharmaceutical firm R&D expenditures to revenues (*R&D intensity*); the natural log of

[16] Results remain robust when a logit model is considered.

pharmaceutical firm market capitalization (*Pharma market cap*); the number of biotech employees (*Bio* employees); the natural log of biotechnology firm shareholder equity (*Bio shareholder* equity); an indicator if the focal alliance is the first one for the biotechnology firm (*First alliance*); the natural log of the amount of public equity raised in biotechnology (IPOs) in the year prior to the alliance (*Bio IPO*); the ratio of pharmaceutical firm external R&D expenditures to total R&D expenditures in the year prior to the alliance (*R&D payout*); the natural log of the total value of the alliance (*Size*); an indicator if the lead product was in late-stage clinical testing (*Late stage*); an indicator if the difference between the year of the contract and year of the first alliance in the population for the focal technology is less than or equal to 5 years (*Technology age*); the number of alliances in the population within the focal technology that have been initiated until the focal alliance (*Technology count*); the pharmaceutical firm stock of alliances (*Alliance stock*); and indicators that identify the presence of milestone payments (*Milestone dummy*), equity positions (*Equity dummy*) and royalties (*Royalty dummy*). Year dummies are included in all models. See Table 1 for variable definitions, Table 2 for descriptive statistics and Table 3 for variable correlations.

Across all four models (Model 1 to Model 4) in Table 4, we find a positive and significant impact of *Technology age* on the probability that an alliance contract covers more than one technology. Marginal effects range from 0.3729 to 0.3934 and are all significant at the 1 percent level. This suggests that newer technologies are often coupled together or combined with existing technologies in these agreements. The effects on *Technology count* bolster this finding. The negative coefficient implies that technologies that are less prevalently utilized in the population of alliances are more likely to be coupled with another technology. Taken together we view this as one way to possibly mitigate risk (exchange hazard) of an underlying technology.

Agreements signed where the lead product is in late stage clinical testing (defined as either Phase II or Phase III) are less likely to be associated with contracts that cover more than one technology. The marginal effects on *Late stage* range from negative 0.33 to negative 0.39. This result is consistent with our expectations about later stage research since by the time a drug candidate moves into late stage clinical testing it is more focused and refined with respect to therapeutic category and underlying technology.

We next consider the effect firm size and capabilities have, if any, on contractual complexity. Interestingly, we find no effect of pharmaceutical firm size as measured by firm market capitalization, *Pharma market cap*. Simply, the sheer size of a company does not appear to have an effect on the technological depth of a contract. Capabilities, however, do matter. We proxy pharmaceutical firm internal capabilities by Cohen and Levinthal's (1989) measure of absorptive capacity defined as R&D expenditures divided by revenues, *R&D intensity*. They postulate that a firm's absorptive capacity is based on their own internal research and development efforts. As a result, regardless of the external R&D activities, for example strategic alliances, that a company may engage in, the firm still must continue to pursue a comprehensive internal research program (Chesbrough, 2003). We find a positive and significant effect on *R&D intensity* with marginal effects ranging from 0.0926 to 0.0976. Higgins and Rodriguez (2006) show that R&D intensity has a positive influence on a pharmaceutical firm's ability to engage in outsourcing acquisitions. Our findings here suggest that in addition to helping dictate the ability of firms to engage in alliances and acquisitions, it also increases the probability that a specific alliance is technologically deep. This finding complements the extant literature in that it suggests that firms that have the internal capability do not necessarily need to engage in large numbers of alliances, but rather can engage in a smaller number of more "deep" agreements.

The number of employees is a commonly used proxy to measure the size of a firm (e.g., Graham and Higgins, 2007; Rothaermel and Hess, 2007; Shan *et al*, 1994; Acs and Audretsch, 1989). This measure is often used instead of market capitalization data since financial information about private companies is not always available.[17] We find no impact between the number of employees of a biotechnology firm, *Bio employees*, and the probability that a given contract is technologically deep.

In addition to biotechnology firm size, in terms of the number of employees, we also examine the effect that firm financial resources, as measured by *Bio shareholder equity*, have on the ability to engage in complex agreements. We find a positive and significant impact of biotechnology firm shareholder equity, *Bio shareholder equity*, on

[17] BioScan often identifies the number of employees for private biotechnology firms. This allows us to gather at least some information with respect to the size of the firm.

the probability of a technologically deep contract. Marginal effects range from 0.0375 to 0.0407 and are significant at the 10 percent level. As with the pharmaceutical firms, here again, it appears that a biotechnology firm's capabilities, proxied by their assets, are what matter with respect to being able to undertake more technologically deep contractual relationships. These findings complement Lerner and Merges (1998) and Higgins (2007). Firms in stronger financial position are not only able to negotiate from a stronger position, but these firms are also able to engage in more technologically deep relationships.

We find a positive and significant relationship between the presence of milestone payments, *Milestone dummy*, and the probability of a technologically deep contract. Marginal effects range from 0.1264 to 0.1767 and are significant at least at the 10 percent level. We interpret the use of milestone payments as one way pharmaceutical firms are able to help mitigate potential moral hazard issues surrounding alliance agreements. Since research funds are fungible, theoretically, biotechnology firms could use research funds for other internal projects. Milestone payments limit the financial exposure of the pharmaceutical firm while providing an incentive to the biotechnology firm to meet specific, verifiable research goals. Jensen and Thursby (2001) find that royalties and equity are important in dealing with the moral hazard issue surrounding inventor effort. While neither *Royalty dummy* nor *Equity dummy* are significant, we believe milestone payments are acting in much the same way.[18]

Of the remaining independent variables only *Alliance stock* is significant, however it is only negative and significant in Model 2. In further robustness testing, the variable remains unstable. The negative coefficient suggests that as firms engage in larger numbers of alliances the probability that they are technologically deep diminishes. It would seem that these firms just simply engage in larger numbers of more "shallow" alliances. The health of a pharmaceutical firm's research pipeline, *Score* has been shown to impact the allocation of control rights (Higgins, 2007) and the probability that a firm

[18] Jensen and Thursby (2001) focus on university license agreements and do not focus exclusively on the biopharmaceutical industry. Arguably this research is much more basic and early stage as compared to the types of research being conducted at the biotechnology-pharmaceutical firm level. As such, milestone payments seem much more useful in this case. Many of the milestone payment provisions are tied to drug candidates passing various stages of clinical testing.

engages in an acquisition (Higgins and Rodriguez, 2006), however we find that it has no effect on the probability a firm engages in a technologically deep contract.

4.2 Functional scope

Table 5 presents probit estimates for our data regressing *Functional scope* on a series of indicator variables expected to affect the probability that a pharmaceutical firm enters functionally complex agreement.[19] The dependent variable is an indicator y_{it} that assumes a value of one for a given firm *i* in a specific year *t* if that firm enters in to an alliance that contains marketing, manufacturing and/or distribution provisions, and is zero otherwise. Independent variables are the same as we utilized in Table 4. Year dummies are included in all models.

By far the most important factor influencing the functional scope of a contract is the stage of the focal research. The marginal effects for *Late stage* range from 0.3152 to 0.4031 and are significant across all models at the 1 percent level. This finding is not unexpected since focal products in later stages of clinical testing have a higher probability that they will reach FDA approval. As a result, marketing, manufacturing and distribution rights become much more relevant.

In addition to the stage of the focal product, the overall size of the alliance, *Size*, tends to increase the probability that a contract is functionally broad. Marginal effects range from 0.1124 to 0.1387 and are significant at the 1 percent level. While it would appear that alliances dealing with later stage products would increase the overall size of the alliance, the simple correlation between *Late stage* and *Size* is only 0.1870.

Across all four models (Model 1 to Model 4), we find a negative and significant impact of *Technology age* on the probability that an alliance contract is functionally broad. Marginal effects range from negative 0.2174 to negative 0.2716 and are all significant at the 1 percent level. This suggests that newer technologies tend to be apart of contract agreements that focus more on research and development. As these technologies are newer, it makes little sense for companies to negotiate marketing, manufacturing and/or distribution rights. The effects on *Technology count* bolster this finding. The negative coefficient implies that technologies that are less prevalently

[19] Results remain robust when a logit model is considered.

utilized in the population of alliances are more likely to be functionally narrow. Taken together this suggests that biotechnology firms have had some success in delaying the inclusion of these contractual terms. The importance of this will be discussed below when we discuss the allocation of control rights.

Milestone payments which were demonstrated to be important for *Technological scope* are not important here (likewise, the presence of an equity stake, *Equity dummy*, has no effect). However, the presence of royalty payments, *Royalty dummy*, do matter for functional scope. The simple correlation between *Royalty dummy* and *Functional scope* is 0.2216 and marginal effects range from 0.1409 to 0.1861 and are significant at least at the 10 percent level. We can infer that biotechnology firms appear to be more likely to negotiate for royalty payment terms for more functionally broad agreements. Intuitively, this makes sense since the inclusion of marketing, manufacturing and distribution provisions may necessitate negotiations on royalty payments.

The proportion of research and development expenses committed to alliances as measured as a proportion of total research and development expenses, *R&D payout*, has a positive and significant impact on the probability that firms engage in functionally broad agreements. Marginal effects range from 0.0617 to 0.0789 and are significant at least at the 5 percent level. As pharmaceutical firms commit an ever increasing amount of their R&D budgets to external alliances, our finding suggest that the contractual landscape shifts in that the functional scope broadens. This finding ties into overall contractual complexity, which will be discussed in the next section.

None of the remaining independent variables are significant across any of the specifications tested. Unlike the previous results, neither firm capability nor size matter when considering the functional scope of the agreement. Now that both *Technological scope* and *Functional scope* have been addressed individually we combine them and look at overall contract complexity.

4.3 Contractual complexity

As discussed above, the notion of contractual complexity has been studied elsewhere in the literature. While each of these studies explores various definitions of

contractual complexity, no work that we are aware of defines complexity as we have here in a multi-dimensional framework.

Table 6 presents both ordered probit (Model 1 to Model 4) and probit (Model 5 and Model 6) estimates for our data regressing *Complex I* and *Complex II*, respectively, on a series of independent variables expected to affect the probability that a pharmaceutical firm enters a contractually complex agreement.[20] The dependent variable in Model 1 to Model 4 is categorical ranking from one to four describing the complexity of the alliance along the previously discussed two dimensions. The dependent variable in Model 5 and Model 6 is an indicator $y_{it,}$ that assumes a value of one for a given firm *i* in a specific year *t* if that firm enters in a strategic alliance that contains manufacturing and/or marketing provisions, and is zero otherwise. Independent variables are same as those utilized in Table 4 and Table 5. Year dummies are included in all models.

The general proposition of transaction cost economics is that managers attempt to align the features of contractual relationships between firms in order to address issues of technological uncertainty, asset specificity and/or difficult performance measures (Williamson, 1985, 1991). Pharmaceutical firms operate in an atmosphere of extreme technological and research uncertainty with often highly specialized assets. As a result, alliance agreements between pharmaceutical and biotechnology firms tend to be rather detailed. Additionally, most pharmaceutical firms engage in many alliances over time. For example, on average, firms in our sample engaged in approximately 122 alliances. This experience, both in general and through repeated contact with specific biotechnology partners leads firms to become more proficient at constructing agreements. However, there is a split in the extant literature with respect to whether contractual terms or the contracts themselves become more or less complex as firms engage in more and more alliances. The potential financial loss to a firm if they are not contractually protected could potentially reach into the billions of dollars if a new drug is discovered. Given the value of the potential loss and significant uncertainty underlying the technological and scientific risks it would seem logical that contractual safeguards would increase (Williamson, 1985; Klein *et al*, 1978). Ryall and Sampson (2006) find that

[20] Results remain robust when an ordered logit and logit model is considered.

contracts are more complete or detailed when firms have prior alliances. This suggests firms learn to craft more complex contracts as they gain experience.

However, contrary to Williamson (1985) and Klein *et* al (1978), Parke (1993) and Ciccotello and Hornyak (2000) find some evidence of reduced contractual safeguards between firms engaging in repeated contacts. Along with Gulati (1995) they attribute this to increased levels of trust. Since the number of pharmaceutical firms that operate within a particular therapeutic category is relatively small, one would expect that the possibility of future relationships would prevent biotechnology firms from shirking or reneging on a contract. Likewise, as Klein (1980) and Klein and Murphy (1997) discuss, firms with unequal bargaining power, in this case pharmaceutical firms, will also not act opportunistically as this could damage their reputation and limit their potential future alliance partners.

The coefficients on *Alliance stock*, across all models tested, is negative, but is only significant at the 10 percent level in Model 1. Our results, as limited as they may be, seem to support Parke (1993) and Ciccotello and Hornyak (2000). Contractual complexity tends to decline as alliance stock increases. We generate a dummy variable, *Prior*, that equals one if the two firms had a prior alliance before the focal alliance. Models 1 to 6 in Table 6 were recomputed switching out *Alliance stock* with *Prior*. Results were similar to *Alliance stock* in that the coefficients were negative and significant at the 10 percent level, but not across all models. Again, these results appear to support Parke (1993) and Ciccotello and Hornyak (2000).[21] This finding is surprising given the extensive development times and high risk of failure coupled with the possibility of a significant financial payoff.

While cumulative experience appears to favor less complex agreements, alliance inexperience as measured by *First alliance* suggests that contracts are more complex if it is the biotechnology firm's first alliance. This finding is consistent with Williamson (1985) and Klein *et al* (1978) since the level of risk (or perceived risk) on behalf of the

[21] The differences in these studies could be a function of the industries being studied or the definitions of contractual complexity that the various authors are using. In addition, it may be the case that trust and related issues impact the contractual negotiation process and as a result is not observed in final outcome measures we are exploring here. As such we can not distinguish between two possibilities: (1) trust related issues really do not impact underlying contract complexity in our sample or (2) trust related issues are influencing the contract process and we are just simply not detecting the effects with either of our measures. We thank Steve Currall for drawing our attention to this distinction.

biotechnology company (and pharmaceutical firm) is relatively high; the biotechnology firm's research performance is untested in the market.

Across all models and both specifications we find that the greater the resources of the biotechnology firm as measured by *Bio shareholder equity*, the more complex will be the contract. The marginal effect in the probit specification in Model 6 is 0.0378 and is significant at the 10 percent level. As a measure of firm resources, it seems consistent that as those resources increased contracts would begin to include manufacturing, for example, since some of the larger biotechnology firms have these capabilities. Interestingly, we find that the younger the technology, the more likely it is that the contract will be more complex. The coefficients of *Technology age* are positive and significant across all specifications with marginal effects in Model 5 and Model 6 ranging between 0.3303 and 0.3753, respectively. With such a new technology it is doubtful that the phase of the focal candidate is driving the result. The correlation between *Technology age* and *Late stage* is negative 0.2955. It might very well be the newness of the focal candidate that is the reason for the complex contract. With new technologies the uncertainty of outcome is greater and it is possible that firms are simply trying to lock up downstream rights while they are less expensive. Lerner *et al* (2003) show that when contracts get renegotiated, as they would in this case if the downstream rights were excluded, the terms received by the biotechnology firms improve.

Complementing a technology's age is how prevalent the technology has been with respect to its dispersion in the population of biopharmaceutical alliances. We measure technology prevalence by *Technology count* and find that the more prevalent a given technology is in the population of alliances, the less complex the contractual agreement. The coefficient on *Technology count* is negative and significant across all specifications tested and the simple correlation between *Technology* count and *Technology age* is negative 0.3271.

One of the largest overall factors that predict the probability of a complex contract is the phase of the focal product. The negative and significant on the coefficient is interpreted differently here in Table 6 than it was in Table 4 or Table 5. Here in Table 6, recall the dependent variables are *Complex I* and *Complex II*. *Complex I* is defined, as we discussed in Section 3.2, along a continuum. The lower end of the continuum contains

agreements with one technology and a range of contractual breadths (functional scope). The upper end of the continuum contained agreements with technological depth. *Complex II* is a dummy that equals one if the contract is technologically deep (covering more than one technology). As a result, the interpretation of the marginal effects in Model 5 and Model 6 (negative 0.3871 and negative 0.3922, respectively) suggest that as focal candidates move into later stages, they are focused on one technology and this simplicity is reflected upon in the underlying contracts. Moreover, more complex agreements in earlier stages of development support the view that future contingencies are difficult to codify for research intensive firms (Robinson and Stuart, 2007).

Finally, the presence of a milestone payment, *Milestone dummy*, has a positive and significant impact on the probability of a contract being more complex. We find no effect on complexity as a result of the presence of an equity stake, in contrast to Robinson and Stuart (2007), or the presence of a royalty payment. Coefficients on *Milestone dummy* were positive and significant across all models and both specifications with marginal effects ranging from 0.1347 to 0.1722. Milestones clearly are one way to help mitigate the risk and uncertainty associated with undertaking research across multiple technologies. Additionally, milestones can be used as a way to mitigate some of the underlying moral hazard issues inherent in these relationships.

4.4 Allocation of control rights

Consistent with previous work (Lerner and Merges, 1998; Lerner *et al*, 2003; Lerner and Malmendier, 2004; Adegbesan and Higgins, 2007; Higgins, 2007), the total number of control rights allocated to the pharmaceutical firm is the dependent variable, *Total rights*. This dependent variable is tested against various specifications of the same independent variables we utilized in the previously analyses with a few exceptions. Since we are interested in contractual complexity we include our two component parts, *Technological scope* and *Functional scope*. We include the individual components in the reported analysis so we can comment on which, if either, component may be driving the result.[22]

[22] Our composite measure of contractual complexity is considered for robustness purposes.

Given the nature of the dependent variable we test for overdispersion in the data to determine whether a Poisson or negative binomial model is warranted. We test for overdispersion utilizing a likelihood ratio test based on the Poisson and negative binomial distributions (Cameron and Trivedi, 1998). This test tests the equality of the mean and the variance imposed by the Poisson distribution against the alternative that the variance exceeds the mean. We reject the null hypothesis and as a result of overdispersion in our data we utilize a negative binomial model.

Recall contractual complexity, as we define it, is a function of both *Functional scope* and *Technological scope*. In terms of the allocation of control rights only *Functional scope* appears to matter. *Technological scope* is positive but not significant at any reasonable level in any model tested. This implies that the number of underlying technologies in an agreement has no effect on the allocation of control rights. On the other hand, *Functional scope* is negative and significant with coefficients ranging from negative 0.1714 to negative 0.1825. For those contracts that contain either marketing or manufacturing provisions, pharmaceutical firms concede focal rights to biotechnology firms.[23] The natural question then becomes is do pharmaceutical firms use the focal rights to "pay" for marketing and/or manufacturing rights. In order to test this hypothesis we construct a new variable *Functional scope II*. *Functional scope II* is defined as a dummy that equals one if contract not only contains marketing, manufacturing or distribution provisions but those rights are allocated to the pharmaceutical firm. When we replace *Functional scope* with *Functional scope II* and repeat Models 4 to 7 we obtain coefficients ranging from negative 0.2432 to negative 0.3374 that are significant at least at the 5 percent level. As a result, we can reasonably argue that pharmaceutical firms "pay" for the marketing and/or manufacturing rights with the focal rights. This finding is unique in that it shows that pharmaceutical firms are able to "trade" or "purchase" specific rights with other rights and not just financial terms, which we discuss below.[24]

---

[23] Recall from Section 3.1 we define our focal rights under the headings of intellectual property rights, licensing rights and exit rights.

[24] This result allows us to indirectly observe firm preferences for specific control rights. The extant literature, unfortunately, has only been able to observe ex post allocations of rights. From this preferences can be inferred but what can not be determined is whether or not a firm preferred a specific right and as a result was willing to "pay" or "trade" other rights in order to obtain the right(s) that they preferred. While we suffer from the same ex post allocation of rights, we are able to show that a "trade" or "payment" of rights occurred between the focal rights and marketing and/or manufacturing rights.

We follow Higgins (2007) and measure the relative bargaining position of the pharmaceutical firm using a weighted measure of the firm's research pipeline, *Score*. The rational behind the use of this measure is simple. Pharmaceutical firms that have weak (or weakening) research pipeline portfolios are in a weakened bargaining position. As a result, biotechnology firms should be able to take advantage of this weakened bargaining position and obtain additional rights. We find this to be the case across all models tested in Table 7. The coefficients on *Score* are positive and significant ranging from 0.0740 to 0.0803. Pharmaceutical firms that have healthier research pipelines are in a stronger negotiating position and as a result are able to extract rights from their biotechnology partners. The converse is thus also true. This finding is consistent with Higgins (2007). Clearly, relative bargaining position of the pharmaceutical firm matters in the allocation of control rights.

Aghion and Bolton (1992), Holmstrom and Tirole (1997), Lerner *et al* (2003) and Higgins (2007) find that research projects in earlier stages of development, which are presumably those with larger information asymmetries and in greater need of financing, are associated with a transfer of control rights to the pharmaceutical firm. The variable *Late stage* equals one if the lead product in the alliance is in Phase II or Phase III clinical testing. Coefficients in Models 2 to Model 7 range from negative 0.1187 to negative 0.2023 and are significant at least at the 10 percent level. The direct interpretation of these coefficients imply pharmaceutical firms give up control rights to biotechnology firms for products in late-stage clinical testing. The inverse interpretation is that rights are transferred to pharmaceutical firms for projects in earlier stages of development. This finding is consistent with the aforementioned empirical work but is in contrast to the theoretical predictions of Aghion and Tirole (1994).

We have already shown that pharmaceutical firms appear to be "trading" or "paying" for marketing and manufacturing rights with the focal rights being discussed. Now we consider whether firms are able to "pay" for additional rights with a variety of financial terms. In order to determine this we focus on the effects of our direct financial incentives: *Milestone dummy*, *Equity dummy*, and *Royalty dummy*. We also consider the overall size of the alliance, *Size*.

It appears that pharmaceutical firms are able to directly "pay" for additional control rights through the inclusion of milestone payments in the contracts. This seemingly is a win-win for pharmaceutical firms since they not only obtain additional rights but milestone payments help alleviate some of the moral hazard problems inherent in this highly uncertain environment. Since money is fungible biotechnology firms could possible use funds for other research purposes. However, by linking financial rewards with scientific progress, pharmaceutical firms can keep biotechnology firm efforts focused on the alliance. Coefficients on *Milestone dummy* range from 0.1361 to 0.1606 and are significant at least at the 5 percent level across all models.

Interestingly, the presence of an equity stake has a negative and significant impact on the number of rights allocated to the pharmaceutical firm. This suggests that biotechnology firms are able to sell equity positions in their firm in order to garner additional focal control rights. The in effect can buy additional rights using their firm as their currency of exchange.

The effect of the *Size* is minimal it is only significant in Model 1 and remains unstable and mostly not significant in robustness testing. We believe that the negative relationship may be tied to the phase of the product which is the focus of the alliance.

Of the remaining variables none of them are significant across the various specifications tested. We specifically discuss two sets of these variables given results in the extant literature. First, for these groupings of contracts the availability of public (or private) financing has no significant effect on the allocation of rights. Lerner *et al* (2003) and Higgins (2007) both report negative relationship between the availability of public financing, *Bio IPO*, and the allocation of rights. Biotechnology firms are in a better bargaining position if they are not captive to the pharmaceutical firms for alliance financing.

Second, we find no effect on *Alliance stock* on the allocation of rights. Furthermore, in robustness testing we find no effect on the presence of a prior alliance between the two firms that are the focus of the current alliance. Consistent with our prior findings discussed in Section 4.3, we do not find that increased experience in either alliances or with a particular partner translates into any advantage or disadvantage with respect to the allocation of control rights. Combined with the results in Section 4.3, it

appears that firms may very well learn to write "better" or more complete contracts, however, they do not appear to be anymore or less complex, in contrast to the findings of Ryall and Sampson (2006) nor does this experience appear to translate into additional control rights.

5.0 Robustness

In order to ensure the robustness of the results to model selection the results from Tables 4, 5 and 6 are regenerated using a logit specification (and ordered logit in the case of Models 1 to 4 in Table 6). None of the results presented are qualitatively different using either of these specifications.

We also want to ensure that our results are not sensitive to small changes in the underlying set of conditioning variables. In order to determine if the results in Models 1 to 4 in Table 6 and Models 1 to 7 in Table 7 are model dependent we borrow from the macroeconomics literature and implement Levine and Renelt's (1992) version of Leamer's (1983, 1985) extreme bound analysis (EBA). In response to sensitivity issues, Leamer (1983, 1985) proposes an EBA to identify "robust" empirical relations. For a specific variable of interest, the extreme bounds of the distribution of the associated coefficient estimates are calculated as the smallest and largest values that are not rejected at the 0.05 significance level given all possible combinations of the remaining conditioning variables taken 3 at a time. If the two bounds have differing signs, then the variable is labeled as fragile; otherwise it is labeled robust. Of the 9 conditioning variables in Models 1 to 4 in Table 6 that are significant, all but two (*Alliance stock* and *R&D payout*) can be labeled robust. Likewise, for the 7 variables that are significant in Table 7 all but two (*R&D payout* and *Size*) can be labeled robust. As a result, we can be fairly confident that the results we present are not model dependent.

6.0 Conclusion

In this paper we attempt to bridge two literatures together and in doing so we make several contributions. First, we extend the literature on contractual complexity by modeling complexity in a multi-dimensional framework. This framework allows us to focus on both the functional scope and technological scope of an agreement. We believe

this is one of the first studies to specifically control for and analyze the underlying technologies of an alliance agreement. Second, we take our framework and analyze the determinants that increase the probability an alliance agreement will be more complex. Third, we tie the contractual complexity literature to the control rights literature by analyzing the relationship between contract structure and rights allocation. Finally, we find that as a firm's stock of alliances increases or if they have had prior relationships with a partner that contracts tend, on average, to be less complex. Our focus on the biopharmaceutical industry makes these findings all the more interesting given long product development cycles (DiMasi, 2001) and potential significant payoffs within highly risky and uncertain environments.

No research is without limitations. We know from previous work that strategic alliances create shareholder value (Higgins, 2007; Chan *et al*, 1997; McConnell and Nantell, 1995). Shareholder value in these studies was measured by cumulative abnormal returns (CARs) around the announcement of the alliance. However, it can be argued that the market was responding to the announcement of the alliance and its future research prospects without full information of the underlying contract (in most cases the contract would not be publicly available at that time). While the prospects of an alliance might be rewarding, the devil, as it is said, is in the details. As Adegbesan and Higgins (2007) point out, it is how the underlying control rights are allocated in a contract that determines how a firm will benefit. Our goal with this research has been to expose another layer in strategic alliance research, analyze underlying contracts and demonstrate that they matter. By doing so, we believe, we have successfully linked the contractual complexity literature with the control rights literature. The next evolution will be to address the question of how these contracts impact firm performance and shareholder value. Doing so, we believe, requires a fine grain analysis of firm level alliance research data and mapping that to subsequent firm and shareholder performance. We leave this task for future work.

References

Acs, Z., Audretsch, D., 1989. Entrepreneurial strategy and the presence of small firms. Small Business Economics 1, 193-213.

Adegbesan, T., Higgins, M., 2007. Intra-alliance performance, control rights and today's split of tomorrow's value. Unpublished working paper, Georgia Institute of Technology.

Adegbesan, T., Ricart, J., 2005. Resource complementarity and the determinants of the distribution of value created by technological innovation. Unpublished working paper, University of Navarra.

Adler, P., 2001. Market, hierarchy, and trust: the knowledge economy and the future of capitalism. Organization Science 12(2), 214-234.

Aghion, P., Bolton, P., 1992. An incomplete contract approach to financial contracting. Review of Economic Studies 59, 473-494.

Aghion, P., Tirole, J., 1994. On the management of innovation. Quarterly Journal of Economics 109, 1185-1207.

Barthelemy, J., Quelin, B., 2006. Complexity of outsourcing contracts and ex post transaction costs: an empirical investigation. Journal of Management Studies 43(8), 1775-1797.

Bernheim, B.D., Whinston, M.S., 1998. Incomplete contracts and strategic ambiguity. American Economic Review 88, 902-932.

Bradach, J., Eccles, R., 1989. Price, authority, and trust: from ideal types to plural forms. Annual Review of Sociology 15, 97-118.

Cameron, A.C., Trivedi, P.K., 1998. *Regression Analysis of Count Data*. Econometric Society Monograph No. 30, Cambridge University Press.

Chan, S., Kensinger, J., Keown, A., Martin, J., 1997. Do strategic alliances create value? Journal of Financial Economics 46, 199-221.

Chesbrough, H.W., 2003. Open innovation: The new imperative for creating and profiting from technology. Boston, Harvard Business School Press.

Cheung, S., 1983. The contractual nature of the firm. Journal of Law and Economics 26, 1-21.

Ciccotello, C. S., Hornyak, M. J., 2000. Cooperation via contract: an analysis of research and development agreements. Journal of Corporate Finance 6, 1-24.

Coase, R.H., 1937. The nature of the firm. Economica 4, 386-405.

Cohen, W., Levinthal, D., 1990. Absorptive capacity: a new perspective on learning and innovation. Administrative Science Quarterly 35. 128-152.

Davidson, W. H. and D.G. McFetridge. 1984. International technology Transactions and the Theory of the Firm. Journal of Industrial Economics 32(3), 253-264.

Dessein, W., 2005. Information and control in alliances and ventures. Journal of Finance 60(5), 2513-2550.

DiMasi, J.A. 2001. New drug development in U.S. 1963-1999. Clinical Pharmacology and Therapeutics 69, 286-296.

Dyer, J., Singh, H., 1998. The relational view: cooperative strategy and sources of interorganizational competitive advantage. Academy of Management Review 23, 660-679.

Elfenbein, D., Lerner, J., 2003. Ownership and control rights in internet portal alliances, 1995-1999. Rand Journal of Economics 32(2), 356-369.

Graham, S., Higgins, M.J., 2007. The impact of patenting on new product introductions in the pharmaceutical industry. Unpublished working paper, Georgia Institute of Technology.

Granovetter, M., 1985. Economic action and social structure: the problem of embeddedness. American Journal of Sociology 91(3), 481-510.

Greene, W.H., 2003. *Econometric Analysis*. 5th ed. Upper Saddle River, NJ: Prentice-Hall.

Grossman, S.J., Hart, O.D., 1986. The costs and benefits of ownership: a theory of lateral and vertical integration. Journal of Political Economy 94, 691-719.

Gulati, R., 1995. Does familiarity breed trust? The implications of repeated ties for contractual choice in alliances. Academy of Management Journal 38, 85-112.

Gulati, R, Nickerson, J., 2007.Interorganizational-trust: the Choice of Make, Buy, or Ally; and the Performance of Interorganizational Relationships in the U.S. Auto Industry," Unpublished working paper, Washington University in St. Louis.

Hart, O.D., Moore, J., 1988. Incomplete contracts and renegotiation. Econometrica 56, 755-785.

Heiman, B., Nickerson, J., 2004. Empirical evidence regarding the tension between knowledge sharing and knowledge expropriation in collaborations. Managerial and Decision Economics 25, 401-420.

Higgins, M.J., Rodriguez, D., 2006. The outsourcing of R&D through acquisition in the pharmaceutical industry. Journal of Financial Economics 80, 351-383.

Higgins, M.J., 2007. The allocation of control rights in pharmaceutical alliances. Journal of Corporate Finance 13, 58-75.

Holmstrom, B., Tirole, J., 1997. Financial intermediation, loanable funds, and the real sector. Quarterly Journal of Economics 112, 663-691.

Joskow, P., 1987. Contract duration and relationship-specific investments: empirical evidence from coal markets. American Economic Review 77(1), 168-186.

Joskow, P., 1988. Asset specificity and the structure of vertical relationships: empirical evidence. Journal of Law, Economics and Organization 4, 95-118.

Jensen, R., Thursby, M., 2001. Proofs and prototypes for sale: the licensing of university inventions. American Economic Review 91, 240-259.

Khanna, T., 1998. The scope of alliances. Organization Science 9(3), 340-355.

Khanna, T., Gulati, R., Nohria, N., 1998. The dynamics of learning alliances: competition, cooperation, and relative scope. Strategic Management Journal 19(3), 193-210.

Klein, B., 1980. Transaction cost determinants of "unfair" contractual arrangements. American Economic Review 70, 356-362.

Klein, B., Crawford, R., Alchian, A., 1978. Vertical integration, appropriable rents, and the competitive contracting process. Journal of Law and Economics 21, 297-326.

Klein, B., Murphy, K., 1997. Vertical integration as a self-enforcing contractual arrangement. American Economic Review 87, 415-420.

Leamer, E. 1983. Let's take the con out of econometrics. American Economic Review 73, 31-43.

Leamer, E., 1985. Sensitivity analysis would help. American Economic Review 75, 308-313.

Levine, R., Renelt, D., 1992. A sensitivity analysis of cross-country growth regressions. American Economic Review 82, 942–963.

Lerner, J., Malmendier, U., 2004. Contractibility and contract design in strategic alliances. Unpublished working paper, Harvard University.

Lerner, J., Merges, R.P., 1998. The control of technology alliances: an empirical analysis of the biotechnology industry. Journal of Industrial Economics 46, 125-156.

Lerner, J., Shane, H., Tsai, A., 2003. Do equity financing cycles matter? Evidence from biotechnology alliances. Journal of Financial Economics 67, 411-446.

Luo, Y., 2002. Contract, cooperation, and performance in international joint ventures. Strategic Management Journal 23(10), 903-919.

McConnell, J., Nantell, T., 1985. Common stock returns and corporate combinations: The case of joint ventures. Journal of Finance 40, 519-536.

Mowery, D., Rosenberg, N., 1989. New developments in US technology policy: implications for competitiveness and international trade policy. California Management Review 32(1), 107-124.

Oxley, J., 1997. Appropriability hazards and governance in strategic alliances: a transaction cost approach. Journal of Law, Economics and Organization 13, 387-409.

Parkhe, A., 1993. Strategic alliance structuring: A game theoretic and transaction cost analysis of inter-firm cooperation. Journal of Law, Economics and Organization 13, 387-409.

Pisano, G., 1989. Using equity participation to support exchange: evidence from the biotechnology industry. Journal of Law, Economics and Organization 5, 109-126.

Poppo, L., Zenger, T., 2002. Do formal contracts and relational governance function as substitutes of complements? Strategic Management Journal 23, 707-725.

Reuer, J., Arino, A., 2007. Strategic alliance contracts: Dimensions and determinants of contractual complexity. Strategic Management Journal 28, 313-330.

Robinson, D., Stuart, T., 2007. Financial contracting in biotech strategic alliances. Journal of Law and Economics, *forthcoming.*

Rothaermel, F., Hess, A., 2007. Building dynamic capabilities: innovation driven by individual, firm, and network level effects. Organization Science 18, *forthcoming*.

Ryall, M., Sampson, R., 2006. Do prior alliances influence contract structure. In *Strategic Alliances*, Arino, A., Reuer, J.J. (eds), Houndsmills: Palgrave MacMillian.

Sampson, R., 2004. The cost of misaligned governance in R&D alliances. Journal of Law, Economics and Organization 20, 484-526.

Shan, W., Walker, G., Kogut, B., 1994. Interfirm cooperation and startup innovation in the biotechnology industry. Strategic Management Journal 15, 387-394.

Teece, D., Pisano, G., Sheun, A., 1997. Dynamic capabilities and strategic management. Strategic Management Journal 18(7), 509-533.

Uzzi, B., 1997. Social structure and competition in interfirm networks: the paradox of embeddedness. Administrative Science Quarterly 42, 35-67.

Williamson, O.E., 1985. *The Economic Institutions of Capitalism*, Free Press: New York.

Williamson, O.E., 1991. Comparative economic organization: the analysis of discrete structural alternatives. Administrative Science Quarterly 36, 269-296.

Table 1: Variable List

Variable	Definition/Description
Score	Weighted value (non-monetary) of pharmaceutical firm research pipeline, $year_{t-1}$
Functional scope	Dummy = 1 if the contract included manufacturing and marketing provisions
Technological scope	Dummy = 1 if the contract covers more than one technology
Total rights	Total number of rights allocated to pharmaceutical firm (out of 8 possible rights)
Complex I	Categorical ranking from one to four describing the complexity of of the alliance contract along two dimensions
Complex II	Dummy = 1 if contract is *Complex I* equals "3" or "4"
Revenues	Pharmaceutical revenues (millions of 1999 dollars)
R&D expenditures	Pharmaceutical R&D expenditures (millions of 1999 dollars)
R&D intensity	Pharmaceutical R&D expenditures/sales (millions of 1999 dollars)
Pharma market cap	Market capitalization of pharmaceutical firm (millions of 1999 dollars)
Bio employees	Total number of biotechnology firm employees (thousands), $year_t$
Bio shareholder equity	Biotechnology firm shareholder equity in the year of the alliance (millions of 1999 dollars)
First alliance	Dummy = 1 if the alliance was the first for the biotechnology firm
Bio IPO	Amount of money raised in public equity markets by biotechnology firms in the year prior to an alliance (millions of 1999 dollars)
R&D payout	Pharmaceutical firm external R&D expenditures/total R&D expenditures (millions of 1999 dollars)
Size	Total value of the alliance (millions of 1999 dollars)
Late stage	Dummy = 1 if lead product that is focus of alliance is in Phase II or Phase III clinical testing
Technology age	Dummy = 1 if difference between year of the contract and year of first alliance in population for the focal technology is less than or equal to 5 years
Technology count	Number of alliances in population within the focal technology that have been initiated until the focal alliance
Alliance stock	Total number of prior pharmaceutical alliances until the year before the alliance, $year_{t-1}$
Milestone dummy	Dummy = 1 if milestone payments are present in the alliance contract
Equity dummy	Dummy = 1 if a non-controlling equity position was present in the alliance contract
Royalty dummy	Dummy = 1 if running royalty payments are identified in the alliance contract

Table 2: Descriptive Statistics

Variable	Mean	Median	Standard Deviation	Minimum	Maximum
Score	168.91	124.40	156.43	11.60	824.40
Functional scope (%)	0.30			0.00	1.00
Technological scope (%)	0.33			0.00	1.00
Total rights	3.18	3.00	1.34	0.00	8.00
Complex I	1.96	2.00	0.95	1.00	4.00
Revenues ($)	11146.55	9236.80	8491.40	8.72	40363.20
R&D expenditures ($)	1186.87	1189.50	819.83	5.25	4435.00
Pharma market cap ($)	49570.51	37519.00	45191.26	99.57	216049.00
Bio employees	0.470	0.137	2.24	0.002	28.10
Bio shareholder equity($)	139.64	27.28	582.38	0.80	6119.00
First alliance (%)	0.06			0.00	1.00
Bio IPO ($)	4673.22	4200.00	2055.05	900.00	8500.00
R&D payout (%)	0.08	0.04	0.11	0.00	0.47
Size ($)	57.64	37.50	81.41	0.50	815.00
Late stage (%)	0.22			0.00	1.00
Technology age	0.22			0.00	1.00
Technology count	214.34	120.00	221.90	0.00	881.00
Alliance stock	121.87	88.00	113.60	1.00	551.00
Milestone dummy (%)	0.54			0.00	1.00
Equity dummy (%)	0.51			0.00	1.00
Royalty dummy (%)	0.44			0.00	1.00

Table 3: Correlation Matrix

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Score	1.0000																			
2. Functional scope	-0.0361	1.0000																		
3. Technological scope	-0.0779	-0.2057	1.0000																	
4. Total rights	0.1190	-0.2374	0.1256	1.0000																
5. Complex I	-0.0938	0.2803	0.2817	0.0088	1.0000															
6. R&D intensity	-0.0384	-0.0646	0.0981	0.0516	0.0651	1.0000														
7. Pharma market cap	0.4000	0.0195	-0.0623	0.0093	-0.0517	-0.2313	1.0000													
8. Bio employees	0.0381	-0.0814	-0.0477	-0.0533	-0.0860	0.0054	0.0293	1.0000												
9. Bio shareholder equity	0.0399	-0.0605	-0.0345	-0.0635	-0.0629	0.0475	-0.0382	0.7904	1.0000											
10. First alliance	-0.0881	0.1181	0.0545	0.0108	0.1104	-0.0175	-0.0491	-0.0413	-0.0468	1.0000										
11. Bio IPO	0.2517	-0.0272	-0.0226	-0.0062	-0.0353	0.0551	0.3879	0.0572	0.0664	0.0388	1.0000									
12. R&D payout	0.0215	0.0405	0.1840	-0.0413	0.2000	-0.0477	0.1357	-0.0379	-0.0881	-0.1126	-0.1739	1.0000								
13.Size	0.2232	0.2046	0.0280	-0.0551	0.1261	-0.0357	0.1923	0.0650	0.1346	-0.0639	0.1254	0.0443	1.0000							
14. Late stage	0.0327	0.3885	-0.3369	-0.1997	-0.1432	-0.0553	0.0482	0.0797	0.0708	-0.0071	0.0360	-0.1030	0.1870	1.0000						
15. Technology age	-0.1539	-0.1938	0.3658	0.0783	0.2654	-0.0330	-0.1523	0.0046	0.0356	0.0599	-0.2173	0.2888	-0.1139	-0.2955	1.0000					
16. Technology count	0.1344	0.0252	-0.1854	-0.0034	-0.1698	-0.0057	0.2078	0.2118	0.1584	-0.0102	0.1653	-0.0771	0.2344	0.2025	-0.3271	1.0000				
17. Alliance stock	0.4727	-0.0725	-0.1124	0.0956	-0.1452	-0.0698	0.5297	0.0338	0.0664	-0.0864	0.2567	0.0002	0.1888	-0.0050	-0.2593	0.2583	1.0000			
18. Milestone dummy	0.0294	0.2697	0.0852	0.0879	0.2136	0.0461	0.0446	-0.0755	-0.1168	0.0521	0.0337	0.0685	0.2015	0.2126	-0.0645	0.1691	-0.0114	1.0000		
19. Equity dummy	-0.1169	0.1296	0.0118	-0.1891	0.0727	-0.0958	-0.1409	-0.1401	-0.1383	0.1056	-0.0715	-0.0419	0.1168	0.0541	0.0210	-0.0791	-0.0444	0.0906	1.0000	
20. Royalty dummy	-0.1004	0.2216	0.0026	-0.0639	0.1093	-0.0897	-0.0800	-0.1145	-0.1156	0.0952	-0.0993	0.0744	-0.1231	0.1272	0.0894	-0.0369	0.0232	0.3254	0.0954	1.0000

Table 4: Technology Scope Regression Analysis

	Model 1	∂F/∂x	Model2	∂F/∂x	Model 3	∂F/∂x	Model 4	∂F/∂x
Score	-0.1278				-0.1645		-0.1582	
	(0.1430)				(0.1534)		(0.1605)	
R&D intensity	**0.2921**[b]	0.0976	0.2359		**0.2864**[c]	0.0926	0.3152	
	(0.1442)		(0.1513)		(0.1511)		(0.2328)	
Pharma market cap	0.0388		0.1028		0.0967		0.0159	
	(0.1025)		(0.0978)		(0.0923)		(0.1285)	
Bio employees			-0.1028				-0.0348	
			(0.0876)				(0.0600)	
Bio shareholder equity			**0.1322**[c]	0.0407	**0.1172**[c]	0.0378	**0.1201**[c]	0.0375
			(0.0710)		(0.0678)		(0.0692)	
First alliance			0.4437				0.3989	
			(0.4442)				(0.4665)	
Bio IPO	0.0584				0.2985		0.4497	
	(0.3860)				(0.3390)		(0.4179)	
R&D payout	0.0672						0.0891	
	(0.0838)						(0.0979)	
Size	0.1347		0.0869				0.1132	
	(0.1202)		(0.1212)				(0.1333)	
Late stage	**-1.665**[a]	-0.3820	**-1.9465**[a]	-0.3796	**-1.4436**[a]	-0.3347	**-1.9933**[a]	-0.3939
	(0.3795)		(0.4377)		(0.3861)		(0.4775)	
Technology age	**1.0573**[a]	0.3867	**1.0906**[a]	0.3835	**1.0921**[a]	0.3934	**1.0535**[a]	0.3729
	(0.2683)		(0.2907)		(0.2874)		(0.2990)	
Technology count			**-0.0014**[b]	-0.0004	**-0.0011**[b]	-0.0003	**-0.0014**[b]	-0.0004
			(0.0005)		(0.0005)		(0.0006)	
Alliance stock	-0.0016		**-0.0025**[c]	-0.0007	-0.0013		-0.0023	
	(0.0012)		(0.0013)		(0.0012)		(0.0014)	
Milestone dummy	**0.3841**[c]	0.1264	**0.5816**[b]	0.1742	**0.5586**[b]	0.1767	**0.5385**[b]	0.1645
	(0.2306)		(0.2400)		(0.2311)		(0.2635)	
Equity dummy	0.0701						-0.0082	
	(0.2225)						(0.2627)	
Royalty dummy	-0.1819						0.0858	
	(0.2507)						(0.2936)	
Year Fixed Effects	Y		Y		Y		Y	
N	220		200		207		190	
Wald χ^2	60.57		61.38		56.97		57.48	
Psuedo R^2	0.2437		0.2962		0.2377		0.3000	

[a, b], and [c] represent signficance at the 1, 5 and 10 percent levels, respectively

* constant term was included in each regression but was excluded from the table due to space considerations

** we use White (1980) heteroskedasticity-consistent standard errors in all regressions.

Table 5: Functional Scope Regression Analysis

	Model 1	∂F/∂x	Model2	∂F/∂x	Model 3	∂F/∂x	Model 4	∂F/∂x
Score	0.0508						0.0008	
	(0.1504)						(0.1523)	
R&D intensity	-0.0503		0.0850				0.1273	
	(0.1567)		(0.1525)				(0.1423)	
Pharma market cap	0.0204		0.1251		0.0161		0.1049	
	(0.1018)		(0.1137)		(0.0883)		(0.1149)	
Bio employees			-0.7126				-0.5360	
			(0.5771)				(0.5919)	
Bio shareholder equity			0.105		0.0723		0.1108	
			(0.1071)		(0.0754)		(0.1082)	
First alliance							0.8318	
							(0.6803)	
Bio IPO	-0.2134				-0.2619		-0.3999	
	(0.5470)				(0.5078)		(0.5969)	
R&D payout	**0.2327**[a]	0.0707	**0.2241**[b]	0.0617	**0.2479**[b]	0.0789	**0.2575**[b]	0.0731
	(0.0953)		(0.1011)		(0.0982)		(0.1055)	
Size	**0.4564**[a]	0.1387	**0.4083**[a]	0.1124			**0.4327**[a]	0.1227
	(0.1285)		(0.1197)				(0.1208)	
Late stage	**0.9119**[a]	0.3152	**1.0198**[a]	0.3323	**1.1289**[a]	0.4031	**1.0812**[a]	0.3605
	(0.2633)		(0.2786)		(0.2545)		(0.2908)	
Technology age	**-1.2001**[a]	-0.2716	**-1.0578**[a]	-0.2174	**-0.8456**[a]	-0.2201	**-1.0891**[a]	-0.2313
	(0.3405)		(0.3341)		(0.3119)		(0.3394)	
Technology count	-0.0007		**-0.0010**[c]	-0.0002	-0.0006		**-0.0010**[c]	-0.0002
	(0.0005)		(0.0005)		(0.0005)		(0.0006)	
Alliance stock	-0.0019		-0.0021				-0.0021	
	(0.0014)		(0.0014)				(0.0015)	
Milestone dummy	0.2793							
	(0.2308)							
Equity dummy	-0.0519							
	(0.2427)							
Royalty dummy	**0.4556**[c]	0.1409	**0.6605**[b]	0.1861	**0.5629**[a]	0.1817	**0.6181**[b]	0.1789
	(0.2578)		(0.2699)		(0.2201)		(0.2753)	
Year Fixed Effects	Y		Y		Y		Y	
N	216		216		203		190	
Wald χ^2	73.94		58.25		58.85		60.00	
Psuedo R^2	0.3308		0.3162		0.2482		0.3390	

[a,b], and [c] represent signficance at the 1, 5 and 10 percent levels, respectively

* constant term was included in each regression but was excluded from the table due to space considerations

** we use White (1980) heteroskedasticity-consistent standard errors in all regressions.

Table 6: Contractual Complexity Regression Analysis

	Model 1	Model 2	Model 3	Model 4	Model 5	∂F/∂x	Model 6	∂F/∂x
Score	-0.0576	-0.0385	-0.0047	-0.0469	-0.1402		-0.1615	
	(0.1093)	(0.1148)	(0.0878)	(0.0941)	(0.1444)		(0.1602)	
R&D intensity	0.1131			0.1698	**0.2969**[c]	0.0969	0.3142	
	(0.0787)			(0.1091)	(0.1646)		(0.2282)	
Pharma market cap	-0.0112	0.0057	-0.0575	-0.0421	0.0260		0.0162	
	(0.0701)	(0.0690)	(0.0683)	(0.0725)	(0.1055)		(0.1229)	
Bio employees		-0.1092		-0.0590			-0.0386	
		(0.0722)		(0.0386)			(0.0587)	
Bio shareholder equity		**0.1200**[b]	**0.1130**[b]	**0.1290**[b]			**0.1210**[c]	0.0378
		(0.0595)	(0.3843)	(0.0590)			(0.0686)	
First alliance		**0.7776**[b]	**0.6365**[c]	0.6555			0.3998	
		(0.3741)	(0.3843)	(0.4239)			(0.4645)	
Bio IPO	-0.0736		-0.1412		0.1461		0.4101	
	(0.3362)		(0.2786)		(0.3737)		(0.3690)	
R&D payout	**0.1167**[c]		**0.1284**[c]	**0.1180**[c]	0.0714		0.0907	
	(0.0674)		(0.0741)	(0.0723)	(0.0850)		(0.0979)	
Size	**0.2871**[a]	**0.2098**[c]	**0.2117**[b]	**0.1992**[c]	**0.1915**[c]	0.0626	**0.1676**[c]	0.0334
	(0.0957)	(0.0949)	(0.0968)	(0.1042)	(0.1047)		(0.1002)	
Late stage	**-0.4406**[b]	**-0.4610**[b]	**-0.4314**[b]	**-0.4133**[c]	**-1.8020**[a]	-0.3871	**-1.9751**[a]	-0.3922
	(0.1990)	(0.2096)	(0.2058)	(0.2157)	(0.3970)		(0.4646)	
Technology age	**0.4895**[b]	**0.6441**[a]	**0.5787**[b]	**0.6311**[a]	**0.9161**[a]	0.3303	**1.0597**[a]	0.3753
	(0.2337)	(0.2466)	(0.2389)	(0.2358)	(0.2751)		(0.2991)	
Technology count	**-0.0010**[a]	**-0.0011**[b]	**-0.0015**[a]	**-0.0013**[a]	**-0.0013**[b]	-0.0004	**-0.0014**[b]	-0.0004
	(0.0003)	(0.0004)	(0.0004)	(0.0004)	(0.0005)		(0.0006)	
Alliance stock	**-0.0017**[c]	-0.0015			-0.0016		-0.0021	
	(0.0009)	(0.0010)			(0.0012)		(0.0013)	
Milestone dummy	**0.4011**[b]	**0.5800**[a]	**0.6065**[a]	**0.5409**[a]	**0.4201**[c]	0.1347	**0.5641**[b]	0.1722
	(0.1911)	(0.1884)	(0.1829)	(0.2004)	(0.2318)		(0.2435)	
Equity dummy	0.0331			0.0492	0.0074			
	(0.1696)			(0.1776)	(0.2296)			
Royalty dummy	0.0303			0.1245	-0.1531			
	(0.1867)			(0.2006)	(0.2532)			
Year Fixed Effects	Y	Y	Y	Y	Y		Y	
N	220	203	203	203	220		203	
Wald χ^2	57.06	50.15	55.71	65.57	65.36		57.9	
Psuedo R^2	0.1045	0.1184	0.1233	0.1283	0.2618		0.2996	

[a,b], and [c] represent signficance at the 1, 5 and 10 percent levels, respectively

* constant term was included in each regression but was excluded from the table due to space considerations

** we use White (1980) heteroskedasticity-consistent standard errors in all regressions.

Table 7: Control Rights Regression Analysis

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Score	**0.0798**[b]	**0.0803**[b]	**0.0776**[b]	**0.0801**[b]	**0.0799**[b]	**0.0740**[c]	**0.0767**[b]
	(0.0397)	(0.0410)	(0.0383)	(0.0388)	(0.0391)	(0.0390)	(0.0391)
R&D intensity	0.0067	-0.0116	-0.0047	-0.0024	-0.0014	-0.0044	-0.0054
	(0.0321)	(0.0344)	(0.0369)	(0.0306)	(0.0305)	(0.0305)	(0.0304)
Pharma market cap	-0.0124	-0.0161	-0.0265	-0.0147	-0.0149	-0.0242	-0.0248
	(0.0276)	(0.0283)	(0.0271)	(0.0263)	(0.0262)	(0.0279)	(0.0280)
Bio employees	-0.0142	-0.0119		-0.0153	-0.0156	-0.0152	-0.0154
	(0.0119)	(0.0138)		(0.0124)	(0.0125)	(0.0125)	(0.0123)
Bio shareholder equity			-0.0390				
			(0.0263)				
Functional scope				**-0.1825**[b]	**-0.1796**[b]	**-0.1714**[b]	**-0.1784**[b]
				(0.0724)	(0.0728)	(0.0718)	(0.0717)
Technological scope				0.0637	0.0552	0.0587	0.0574
				(0.0621)	(0.0646)	(0.0644)	(0.0646)
Bio IPO	0.0916	0.1093	-0.0611	0.0500	0.0583	0.0351	0.0434
	(0.0939)	(0.0868)	(0.0739)	(0.0877)	(0.0890)	(0.0920)	(0.0888)
R&D payout	-0.0400	**-0.0512**[c]	-0.0351	-0.0419	**-0.0437**[c]	**-0.0463**[c]	**-0.0447**[c]
	(0.0272)	(0.0270)	(0.0265)	(0.0264)	(0.0270)	(0.0269)	(0.0269)
Size	**-0.0556**[b]	-0.0416	-0.0329				
	(0.0275)	(0.0289)	(0.0284)				
Late stage		**-0.2023**[b]	**-0.2235**[a]	**-0.1187**[c]	**-0.1336**[c]	**-0.1782**[c]	**-0.1455**[c]
		(0.0820)	(0.0803)	(0.0708)	(0.0701)	(0.0782)	(0.0780)
Technology age		0.0931	0.0982		0.0358	0.0508	0.0459
		(0.0739)	(0.0719)		(0.0772)	(0.0772)	(0.0775)
Technology count			0.0040				
			(0.0100)				
Alliance stock						0.0003	0.0002
						(0.0002)	(0.0002)
Milestone dummy	**0.1398**[b]	**0.1606**[a]	**0.1597**[a]	**0.1361**[b]	**0.1367**[b]	**0.1461**[b]	**0.1447**[b]
	(0.0641)	(0.0607)	(0.0572)	(0.0595)	(0.0595)	(0.0614)	(0.0615)
Equity dummy	**-0.1119**[c]	**-0.1128**[c]	**-0.1407**[b]	**-0.1278**[b]	**-0.1275**[b]	**-0.1351**[b]	**-0.1375**[b]
	(0.0601)	(0.0584)	(0.0581)	(0.0537)	(0.0537)	(0.0540)	(0.0541)
Royalty dummy	-0.0606	-0.0395		-0.0114	-0.0135	-0.0308	-0.0317
	(0.0662)	(0.0658)		(0.0622)	(0.0622)	(0.0653)	(0.0656)
N	203	203	203	203	203	203	203
Wald χ^2	40.28	59.40	49.34	55.50	55.46	56.18	57.95

[a], [b], and [c] represent signficance at the 1, 5 and 10 percent levels, respectively

* constant term was included in each regression but was excluded from the table due to space considerations

** year fixed effects were included in all models

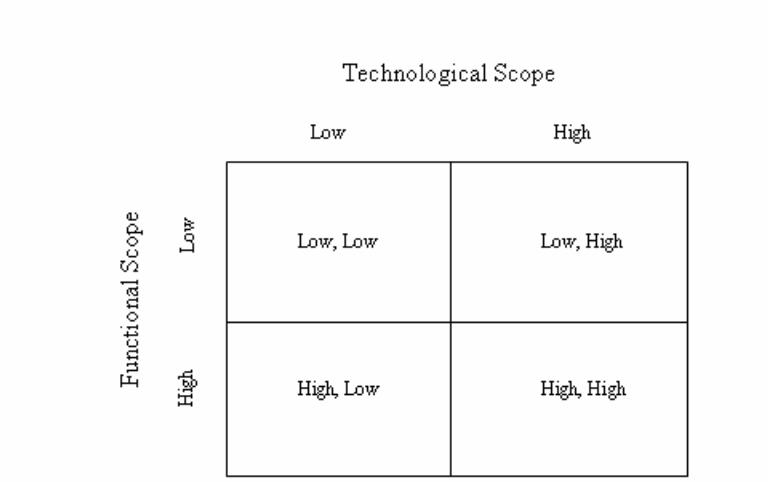

Fig 1. Presents our multi-dimensional framework for contract complexity in a two-by-two matrix. Functional scope is defined as *low* if the alliance agreement focuses solely on research and development and contains only our focal rights. Functional scope is defined as *high* if the agreements include provisions dealing with marketing, manufacturing and distribution. Technological scope is defined as *low* if the agreement focuses on one technology while it is defined as *high* if more than one technology is involved.