Planning for Risk or Planning for Performance? Managing Resource Requirements and Coordination Concerns in Technology Alliance Agreements

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Paper presented at

EMNet 2007 - International Conference on Economics and Management of Networks, Rotterdam, June 28-30, 2007

ABSTRACT

The choice of efficient contractual form is often framed as the selection of a degree of hierarchical intensity suitably matching the level of contractual hazards. We posit that technology collaboration contracts are also responsive to the configuration of resources and to coordination concerns and that contractual solutions may be multidimensional and differ 'in kind'. A sample of joint R&D biotechnology agreements provides broad support for propositions concerning the antecedents. Moreover, we find that the way certain contracts are chosen in response to various contingencies, challenges the idea that they can be usefully characterized as 'intermediate' between polar forms of governance.

KEYWORDS: Governance, contracts, strategic alliances, biotechnology, joint R&D.

INTRODUCTION

Research on contract choices in interfirm alliances has been mainly influenced by transaction cost economics (henceforth, TCE), which explains the choice of governance forms with the presence of transaction-level hazards. Despite expanding its concepts over time, TCE remains chiefly concerned with those contracting problems that would vanish but for the joint occurrence of opportunism and bounded rationality (Williamson 1996: 14). While such problems may be paramount in transactions involving high conflict potential, when the activities contemplated by the partners to an alliance are complex, the governance model adopted is likely to reflect also the concern that the pattern of coordination is suitable for the task at hand. Even more, when an alliance involves exploration activities, the parties ought to be concerned also about their capabilities and the resources they

commit to the task (de Laat 1997; Grandori 2005). Borrowing from legal jargon, we can say that within certain contracts, the planning of *performance* is at least as fundamental as the planning of *risk* (Macneil 1975).

Based on a similar reasoning, Gulati and Singh (1998) advanced the hypothesis that the choice of the alliance form is driven not only by appropriation concerns but also by *coordination requirements.* While Gulati and Singh have found support for their hypothesis, the antecedents of formal alliance governance that could be inspired by classical organizational thinking or by the resource-based view have not been investigated systematically, and have yielded mixed evidence (see, for example, Sampson (2004) and Xia Wang (2005)). This paper further expands on this line of thinking, and analyzes whether other traditional predictors of intra- and inter-organizational coordination modes – uncertainty, interdependence and the distribution of resources – are useful when the explanandum is specifically the formal, enforceable, agreement.

Divergence on the predictors notwithstanding, many studies have often been in practical agreement in treating alliances form as a one-dimensional construct varying along a continuum, usually labeled 'hierarchical intensity' (Oxley 1997, Gulati & Singh 1998) or 'integration intensity' (Xia Wang 2005). However, prior research (Alter & Hage, 1993; Suchman 1994, Brousseau 1995, Furlotti, 2007) has alerted us to the fact that one-dimensional characterizations of inter-firm alliances in general, and of alliance agreements in particular, are bound to leave a lot of the observed variance unexplained.[1]

This state of things provides the occasion for a second purported contribution of this study: allowing for the possibility that different governance forms differ not just in degree but also *in kind*. In particular we shall argue that the choice between arm's length and hierarchical contracts is too

[1] This focus on low dimensional representations seems to be inspired more by analytical convenience than by theoretical reasons. For instance, in Williamson (1991) governance forms are argued to differ by incentive intensity, administrative intensity, adaptability properties and by the type of contract law. For Gulati and Singh (1998: 787; our emphasis) "each governance structure for alliances is typically associated with distinct *types* and levels of hierarchical control". Yet they end up analyzing "the choice across structures [as] one of choosing the appropriate *level* of hierarchical control". While the cited passage reveals a contradiction, their econometric technique – multinomial logistic – does not assume that the dependent variable is ordinal.

stark an alternative, and that certain problems of inter-firm collaboration under conditions of radical uncertainty call for an additional, 'associational' governance model that can hardly be described as an intermediate form.

Our interest in the coordination capabilities of contracts, rather than in their agency features, requires that that the issue is investigated in a setting where coordination and capability requirements are not trivial and where inter-firm alliances are a common means of doing things. This leads quite naturally to the choice of biotechnology alliances as the setting of our research.

We begin our more detailed arguments with a brief investigation of the needs for inter-firm collaboration in the pharmaceutical biotechnology industry. We then discuss what contractual types would be suitable for the governance of such collaborations and provide illustrations by means of mini cases. Then we introduce antecedents inspired by classical organizational thinking and we develop hypotheses about their relationships with different contractual types. The two final sections describe our methodology, analyses, and results and discuss the implications of our findings for scholarly research and practice.

BIOTECHNOLOGY ALLIANCES

Until the '80s drug discovery was based mainly on the random screening of small molecules against targets. Generally the mechanisms of action of therapeutic agents were poorly understood. Large scale screening enjoyed substantial economies of scale, hinged upon fairly routine tasks and was carried out in rather hierarchical work systems (Gambardella 1995: 45). However, from the middle '70s, substantial advances in cell biology, pharmacology and physiology lead to considerable progress in the understanding of the biological roots of many diseases. These developments opened the way for drug discovery to be guided increasingly by scientific hypotheses.

Many of these scientific developments originated outside the domains of chemistry and chemical engineering – the main disciplines on which drug discovery had been based until then. Several of them, particularly those associated with genetic engineering, were, at their roots, process

technologies, that involved a considerable amount of tacit knowledge and could only be learned by actively engaging in practical applications (Pisano, 1996). This hindered a quick transfer of these techniques from the academia to pharmaceutical companies and favored the establishment of new biotechnology firms (NBFs), usually around one or two researchers who had pioneered a particular technology. As a result, pharmaceutical companies found themselves in the need to forge stronger ties with the scientific community and to actively engage in collaborations with NBFs.

While the developments just described seem to favor alliancing of a rather 'thick' type, it is important to recognize that the biotechnology revolution involved different technological trajectories. On one technical trajectory the advances in genetics and molecular biology were used essentially as tools to enhance the productivity of the conventional small molecule synthetic chemical drugs research (Henderson, Orsenigo, & Pisano, 1999: 287). In such cases, the adoption of these technologies was a fairly natural extension of the existing competence base of incumbent pharmaceutical firms, and could be managed by hiring molecular geneticists, or by contracting out certain stages of the discovery process. On a different trajectory, the pursuit of biotechnology required radically new competencies, as it shifted both the method and the domain search for new therapeutic agents. (Henderson et. al., 1999: 288). Owing to the tacitness of some of the process technologies involved, pharmaceutical companies moving along this trajectory had a stronger need to forge thick collaborative ties with NBFs.[2]

Besides strictly technological reasons, other economic and institutional characteristics of the drug development process shape the incentives of industry participants to engage in alliances, and the particular modes of such relationships. Today, even large firms have abandoned the idea of covering an exhaustive range of research areas (Gambardella 1995: 81). At the same time, they cannot afford to totally disregard certain biotechnology-related technological developments, some

[2] Another accepted a typology, that classifies the new research techniques and heuristics into *co-specialized* and *transversal* technologies, also implies different incentives for thick and arm's length collaborations. Co-specialized technologies entail individual analysis and techniques that are specific to given fields of application, while *transversal* technologies involve applicability to multiple biological targets and diseases (Orsenigo, Pammolli & Riccaboni. 2001).

of which might prove quite unsettling for industry incumbents. One way to monitor certain research fields without committing excessive managerial resources is to buy real options on scientific discoveries through 'research-for-fee' agreements of through outright licenses. As compounds are well defined objects such contracts exhibit rather low transaction costs (Gambardella: 55). The need to fill project pipelines in a period of decreasing R&D productivity may also be a motivating factor for such market-like transactions. Nonetheless, it remains true that new compounds arise from information flows and feedbacks between the design stage and applied lab research and that, as a result of the growing use of scientific knowledge in drug discovery, the efficiency of the interaction between upstream theorizing and downstream experimentation, as well as their complementarity, have become more pronounced (Gambardella 1995: 41). This should motivate some genuine research collaborations, conducted by researchers from both the parties of dyadic alliances. In collaborative research, additional factors may direct the choice of the governance models toward a greater focus on control or toward more polyarchic, partnering relationships. Greater demand for control can be motivated by concerns about the appropriability of inventions (Gambardella 1995: 59), by the routine character of the experimentation process (Hopkins, Martin, Nightingale, Kraft, & Mahdi, 2007: 569), by the financial dependency of the biotech partners (Lerner & Merges 1998) and by the corporate culture of large pharmaceutical firms.[3] On the contrary, the complementarity of the competencies that are required in the discovery process, the ethos and the incentives of the scientific community, the efficiency of the decision making process when it addresses complex problems and, finally, the increasing confidence and financial stability of biotech firms (Seget 2006) all seem to inspire more 'organic' and egalitarian collaborations. However, it appears that to-date the antecedents of such a governance model have not been made the object of systematic investigation in the pharmaceutical biotechnology sector.

CONTRACTUAL TYPES

[3] Which, according to Sapienza (1989) are often marked by "bureaucratic stolidity".

TCE argues that under conditions of information complexity coupled with the potential of conflict of interests the control provided for by hierarchical governance is to be preferred to market-based forms. Despite considerable support for this framework, there is also non-negligible evidence to the contrary and evidence indicating that the hypothesized relationships are not significant (e.g. David & Han 2004). Moreover if the word 'hierarchy' is taken at face value, as indicating decision-making structures based on centralized authority (Simon 1962: 468), it is dubious that hierarchical governance structures can be comparatively efficient even in highly uncertain contexts (e.g.: Burns & Stalker 1961). Truly, in many studies inspired by TCE, 'hierarchical intensity' is just a convenient label for a bundle of heterogeneous governance mechanisms. However, even as a short-hand expression this heuristic has limitations as "most arrangements involve multiple dimensions of governance [and] it is extremely difficult to locate actual arrangements on the [market to hierarchy] continuum" (Pisano 1989: 109). All this indicates the need to specify more accurately what the constituent elements of hierarchy are and to consider which of them can adequately serve the goals that are asked of the contractual governance of R&D collaborations. To this purpose we carried out a brief review of some representative studies of inter-firm alliances that have adopted a TCE perspective. Due to space constraints we can only summarize its results here, while some detail is provided in Appendix A. This review reveals that a good portion of the strategic alliance literature agrees that more hierarchical intensity is a suitable remedy for greater contractual hazards. However, the mechanisms that are said to ensure hierarchical control are quite heterogeneous and are likely to have rather different governance properties. Moreover, several of them seem to have little applicability to joint R&D collaboration agreements, particularly in the biotechnology sector. Ownership is excluded by definition. Equity participation is also quite rare in pharmaceutical biotechnology (Roijakkers & Hagedoorn, 2006). As to the sharing of profits or revenues, the perusal of a few alliance contracts reveals that it can be easily established contractually, without necessarily requiring equity investment. Moreover, it hardly discriminates among different alliances (some form of sharing is observed in virtually all of the alliances of our sample), and it arises in

response not only to asset specificity, but also as a remedy to information asymmetry and to ensure fairness (Masten & Lafontaine, 2006). The uncertainty of R&D tasks is problematic also for the use of authority (Radner 1997) and for rules and standard procedures of highly specific content (Grandori 2001). Hostages seem to be somewhat more promising but with some qualifications.[4]

What remains of 'hierarchical' governance, once multiple mechanisms have been ruled out on various accounts, are resource commitments, coupled with arrangements to lock them in for a suitably long period.[5] Before being a safeguard against the risk of opportunism, from a cognitive viewpoint commitments of resources may be the only feasible contracting strategy under conditions of uncertainty. On one side, it is easier to specify ex ante a capability to deal effectively with a certain situation than an action to mechanically cope with it, without intervention of conscious judgment (Knight, 1921: 298). On the other side, resources are characterized by high flexibility and width of possible services and applications (Penrose 1959). Therefore in a sense they 'contain' also those specific applications that will become necessary as a relationship unfolds. Such flexibility largely relieves from the need to ensure adaptability through the specification of many contractual contingencies, which, in turn, eases the burden of verification and makes the contract more enforceable.

Enforceable resource commitments have also the potential to align the parties' interests. To the extent that a party has pledged a resource to the exclusive service of a certain relationship, that party's threat point with regard to that resource is zero. Therefore any benefits from the resource can only be expected if it is put to use in the relationship.[6] In practice, committing resources means contracting over property rights, either specific or residual. Various forms of contractual restraints,

[4] First, the uncertainty of R&D tasks and the difficulty of ex ante specification deliverables can make it extremely difficult to detail the circumstances that would cause the loss of the hostage, and could make the risk of contrived seizure unacceptably high (Williamson 1985). Second, when an alliance is entered with the main purpose of financing a long and uncertain R&D project, the recipient of the finance, particularly if it is as small, cash-constrained company, may not have the resources to post a hostage of sufficient value (Lerner and Malmendier 2005).
[5] This section draws several ideas from Grandori (2001, 2005), (----- and ------- 2006) and (-------- and ---------, 2007).
[6] This function is similar to the one performed by generic contractual hostages. However, the bonding effect is likely to be much stronger and stable – in the face of variability of the payoffs of the game – if the 'hostages' are the very resources that are required to undertake to the project.

forbidding the use of certain resources outside the relationship, could also serve the same purpose (e.g.: non-compete clauses).

An agreement to pool resources also needs to be complemented by rules about the sharing of the surplus, decision-making and the termination of the relationship (Vanberg 1994). In principle, alternative solutions may be viable. However, to the extent that the resources that are pledged to the relationship are different, complementary capabilities from the two parties, allowing both parties to take decisions in their respective domains of expertise and to bear the wealth effects of their decisions serves the purpose of efficiency (Fama & Jensen 1983). Accordingly we would expect that polyarchic decision making and shared residual claimancy would be typically observed in such agreements. Further, to the extent that resources are pooled for the purpose of pursuing an uncertain venture, we would expect to observe longer durations, if not open-ended relationships.

The contracting model just described serves functions that go beyond the safeguard of specific assets and employs a mix of mechanisms that is quite disjoint from that identified in the above-mentioned review of literature. Locating it on the market-hierarchy continuum is rather difficult. We suggest that such model is more conveniently treated as differing 'in kind' from the other two archetypes, and we follow Grandori (2001 and 2005) in designating it as 'associational contracting'.

Although associational contracts can be argued to possess certain advantages under conditions of radical uncertainty, they also entail costs. At a minimum, pooling resources together for the pursuit of a particular project entails the opportunity cost of the economies of scale that might be obtained by serving a series of arm's-length transactions. Thus, for simple transactions market-like contracts may be the preferred alternative. Further, when just one party provides valuable specific knowledge inputs, efficient decision management may require delegating the initiation and implementation of decision to that party, and assigning control to the other, to assuage agency concerns. In this case a more hierarchical governance structure may be advisable (Fama & Jensen 1983). However, as revealed in the above-mentioned review of literature, the practical exercise of control entails a

variety of mechanisms besides formal authority, so that we prefer labeling such structure as 'bureaucratic'.

A close correspondence with the associational archetype has been observed in venture capital financing contracts (Kaplan & Strömberg 2003, Suchman 1994,). By means of three mini-cases in the next section we illustrate how biopharmaceutical alliance contracts also resemble the three contractual models we have just outlined and we provide a description of how they may look in practice.

EVIDENCE FROM CASE STUDIES

The focus of our analyses is on the stipulations concerning the specification of tasks and intellectual resources, on the rules for apportioning costs and revenues, on the assignment of decision-making rights and on the procedures for dispute resolution. The three alliances have very similar backgrounds. All of them were negotiated between biotechnology companies,[7] at very early stages of the development project, and all involve firms of relatively recent establishment.

Market-like contracts: Aurora Biosciences – Allelix Biopharmaceuticals (1997)

Within the framework of this alliance Allelix "engaged" Aurora for a period of three years to develop assays for specific molecular targets and to conduct screening activities with those assays. Upon completion of these activities, Allelix would develop and commercialize promising compounds in its own discretion. In this respect the alliance can be seen as an outright "sale" of Aurora's research services. However, the actual interaction envisaged was somewhat thicker, so that the relationship may be aptly described as an alliance.

This fact notwithstanding, the relationship between these two partners was an arms' length one under many respects. First, the matter of contracting was represented mainly by the actions to be carried out by Aurora. No real 'pooling' of existing resources was established. As a result, the

[7] We follow Recombinant Capital's classification, which assigns alliances to types as 'biotech-biotech', 'drug-biotech', etc.

parties were locked into the relationship only very weakly.[8] Second, the contract seemed to rely mainly on monetary incentives as its main mechanism to ensure the enforcement of its covenants: Aurora was to receive specific payments upon the achievements of certain, specified milestones, while Allelix was deterred from walking away too easily by the stipulation that considerations are paid to Aurora in quarterly installments in advance. The parties set up a very light administrative apparatus to monitor each other's behavior. No budgetary control was provided for and auditing and inspection rights were kept down to a minimum. Finally, the contract did not place any of the standard restraints on the partners, like non-compete clauses or similar behavioral vetoes. In other words, the agreement paid only very limited attention to the process of achieving the goals of the collaboration and it focused much more on its results.

Bureaucratic contracts: Sunesis Pharmaceuticals, Inc. – Biogen Idec (2004)

This collaboration had the purpose to discover and develop small molecule cancer therapeutics targeting a particular family of enzymes that play a major role in the progression of cancer. Despite some similarities, this alliance also showed profound differences with the case analyzed above. First, the focal agreement attempted to describe the activities to be carried out in much greater detail.[9] Second, the planning extended also to future and uncertain activities, through the explicit inclusion of state-contingent clauses (regulating, for example, how the parties would share the costs of third party licenses that might become necessary). Third, the focal agreement set up a complex control apparatus, encompassing budgetary controls ("budgets" are mentioned 46 times in the agreement) inspection rights, periodical reporting and obligations to inform the counterparty about specific matters. Fourth, unlike all the other alliances reviewed, the Sunesis-Biogen agreement made an

[8] The parties reciprocally granted licenses to carry out the necessary research activities, but these licenses would cease as soon as the alliance was terminated, and both had the right of unilateral termination for convenience. Moreover, the agreement assigned new inventions developed within the collaboration to the parties depending on their technological area, to avoid encroachments on each other's expertise.

[9] One exhibit of the contract contains a Gannt chart which enlists 59 activities. A second exhibit reproduces a decision tree for the advancement of the project. Other exhibits, detail specific criteria for determining a 'hit compound' and a 'lead compound' (e.g.: "MW <600", "Stability in human plasma, liver microsomes [*]% after 1 hr", etc.). These and other specifications greatly inflated the length of the contract. The 204 double-spaced equivalent pages of this agreement are about three times those of the Aurora-Allelix alliance and ten times those in the Apollo-Endocon contract.

important derogation to the principle of unanimous consent by which most joint steering committees of biotechnology alliances operate: in case of disagreement on matters assigned to the responsibility of the committee, Biogen had the right to cast a deciding vote. All in all, the focal agreement clearly differs from the previous one for its more complex administrative apparatus, as well as for a certain lopsidedness in the assignment of decision rights. However, the thoroughness with which the terms and conditions for exercising certain options for exiting the alliance were stipulated, differentiate it also from the ideal type of an association of resources to be maintained 'no matter what', which is quite well exemplified by the next case.

Associational contracts: Endocon, Inc. – Apollo Genetics Inc. (1996)

The goal of this alliance was to develop a subcutaneous implant for the long-term, controlled delivery of estrogen for the treatment of Alzheimer's disease. The alliance agreement stands out for its conciseness. In just 20 pages the parties specify the terms of their collaboration. No specific actions are envisaged. Simply, the parties agree to collaborate in the joint development of formulations for a specific indication, grant each other licenses to their respective background technologies (listed at the end of the agreement), and assign the rights to manufacture the product (to Endocon) and to commercialize it (to Apollo). The parties also agree that the proceeds of the collaboration, net of reimbursement of expenses incurred, shall be allocated 60% to Apollo and 40% to Endocon. This 'community of fate' is intended to be perpetual.[10]

Apparently the parties trust that this associational core will suffice to integrate their respective interests. As a result, several aspects remain unspecified.[11] Rather, the contract focuses on procedural aspects, like the management of the collaboration and the dispute resolution procedures. Decision-making rights on all contractual relationships created by the agreement are assigned to a

[10] Truly, each party is granted the right to terminate the alliance upon 60 days' written notice. However, in such case all rights to the product would go to the non-terminating party.

[11] For instance, the parties agree to agree, prior to the start of commercialization, on 'the alternative financial terms of the said license'. Moreover, no project is mentioned in the agreement. Yet, given the stage at which the alliance is negotiated, the collaboration will certainly require several research and development activities in order to achieve its purpose.

joint research committee with equal representation of the parties, which decides by unanimous consent. In case of disagreements disputes escalate to senior executives of the two companies. On no specific decisions does a party have a final say in case of controversy.

Although each particular case presents specificities that challenge abstract typologies, the three alliances analyzed seem to be representative of rather different models of organizing interfirm relationships centering respectively on monetary incentives, on control procedures and unilateral decision making, and on binding together complementary resources.

These descriptions illustrate the usefulness of analyzing the formal governance of interfirm alliances at the level of individual contractual provisions and of considering several of them simultaneously. Much of the heterogeneity we have seen would escape undetected when measured by means of traditional indicators.[12]

PREDICTORS OF FORMAL ALLIANCE GOVERNANCE

What influences the choice of the contractual governance of alliances? The factors we consider are referable to two fundamental ways of viewing organizations: the first focusing on the task dimensions, the second emphasizing resources. Uncertainty and interdependence are probably the most representative constructs under the first perspective.

Uncertainty and interdependence

Contracting is supposed to require the specification of actions and/or of goals, particularly in a 'classical' contracting perspective (Macneil 1974).[13] In general uncertainty hinders meaningful specification, that is, the greater the uncertainty, the more detailed specification becomes dysfunctional (Al-Najjar 1995, Bernheim & Winston 1998).

[12] For instance, in a framework that relies on 'minority equity investment' as an indicator, the first and the last alliances would be treated as similar, as neither of them has any equity investment. The second alliance, on the contrary would be classified as more 'hierarchical' due to a 14 million USD issue of shares by Sunesis to Biogen. However, one may wonder whether the tighter control that the client obtains in this alliance owes to the equity investment or, rather, to the aforementioned contractual stipulations. In fact Biogen's investment took place through the purchase of preferred shares (which usually do not give the owner voting rights) and did not grant the investor any seat in the partner's board.

[13] The promise relates to something, not to everything (Macneil 1974: 715).

Interdependence is an intermediate and composite variable that is used often as a concise predictor of organizational solutions, but it is rarely found as a predictor in the literature on inter-firm contracting (Shelanski & Klein 1995; David & Han 2004; Furlotti 2007). Exceptions are Mayer and Bercovitz (2003) and Mayer and Nickerson (2005). The classical types of interdependence have been investigated mainly with reference to going concerns, focused on the exploitation of a given technology (Thompson 1967), and with reference to flows of tangible resources. By contrast, technological alliances often focus on exploratory activities, are usually assigned a specific time bracket and rely largely on immaterial inputs. As a result the defining criteria of interdependence need to be adapted to a context where a smooth flowing of goods is not a particularly critical element for success and the basic patterns of interdependence need to be figured-out ex-ante, at the contracting stage. This task is delegated to the next section. However, one variable that we shall investigate under the rubric of interdependence – alliance scope – requires justification. In classical organization studies, 'scope' is an attribute of task, and is one dimension of technology (Dewar & Hage 1978). Here we are concerned with 'scope' in a slightly different sense. In particular, we want to analyze whether carrying out the commercial exploitation of the results of the R&D activity within the umbrella of the same alliance that generated them brings consequences for the choice of the alliance contractual governance. Thus, in our definition 'scope' measures the range of functional activities.[14]

Distribution of resources

Resources matter in many respects. Here we shall focus only on the extent to which one type of resources – scientific know-how – is contributed to an alliance by a single party or by both of them. The concept of 'alliance' entails the notion of collaboration among parties that are peers, in some sense (Oxley & Silverman 2007). Yet with respect to particular classes of resources quite uneven contributions can be observed.

[14] We shall argue later that when specified in this sense alliance scope samples more within the conceptual domain of interdependence than within the domain of complexity.

In other settings, it could be argued that the balance of resource contributions is, at least to some extent, endogenous to the relationship. However, in high technology sectors, and in pharmaceutical biotechnology in particular, the parties are unlikely to have many degrees of freedom concerning resources. Clearly, in knowledge intensive collaborations, often involving cutting-hedge technology, the balance of knowledge resources is largely dictated by the partners' respective capabilities.

HYPOTHESES DEVELOPMENT

In developing hypothesis about the relations between contractual types and their predictors, we shall apply the logic of discrete structural alternatives approach (Williamson 1991). Therefore, unless otherwise specified, all the hypotheses below will state the desirability, from an efficiency point of view, of a particular contractual form relative to market contracting.[15]

Uncertainty and contractual type

Task uncertainty is often used as a predictor in empirical studies investigating contractual design. In general, there seems to be convergence of results supporting the proposition that greater uncertainty favors the adoption of less specific (i.e., less detailed, more ambiguous) contractual clauses (e.g. Crocker & Reynolds 1993, Ryall & Sampson 2006) and of less complex contracts (i.e., shorter, with fewer provisions) (Poppo & Zenger 2002, Saussier 2000). In terms of our typology, this is unfavorable to the adoption of bureaucratic contracts.

Further indications can be obtained from the classical organizational theory. The generic bureaucratic model is characterized by standardization, formalization, specialization and centralization (Pugh, Hickson, Hinings, MacDonald, Turner & Lupton 1963). Standardization and formalization (in the specific sense of a detailed writing and filing of procedures), are at a disadvantage when the problem to be solved requires the pursuit of not previously attempted combinations of actions and resources (Burns & Stalker 1961). As to centralization, it may have

[15] However, as we do not assume an ordinal relationship between different contract types, contracts other than market-like need to be assessed against each other. In that case our term of comparison will be clearly made explicit.

contrasting implications for efficiency. On one side, innovation often requires the combination of different knowledge bases, which are the more difficult to master the more they are cognitively distant from one another. In turn, this lack of mastery may cause centralized authority to fail (Radner 1997). On the other side, a central monitoring authority may be useful to prevent shirking and multitasking (Holmström & Milgrom 1991), to safeguard against knowledge spillovers (Oxley 1997) and to coordinate those aspects of the innovation process that have become to some extent routinized. These arguments indicate that upon carefully balancing its various mechanisms, the bureaucratic model may not be wholly unsuitable for managing technological alliances.

Further we can argue that under conditions of radical, non-probabilistic uncertainty simple ex-post adaptation may not be enough of a solution to contracting problems since what is required is rather the construction of a valid model of the world (Grandori 2001). At an organizational level, the construction of such a model obviously benefits from the application of intellectual resources that are sufficient by quantity and related by epistemic domain. This almost self-evident proposition derives from general characteristics of problem solving (Pólya, 1945) and implies that relevant knowledge resources are less than perfectly substitutable.[16] For these reasons we can argue that organizational structures that ensure the bonding of a certain amount of specialized resources to the mission of solving an epistemically complex problem should on average outperform alternative structures where resources are insufficient, are not specialized, are made available intermittently or are frequently diverted to competing goals.

While bound to some extent to the solution of the focal problem, the resources brought to bear on it cannot be overly constrained, lest they lose the possibility of creating those novel combinations of activities and resources upon which innovation is typically based (von Hippel, 1988). The foreclosure to resources of the opportunities to be applied outside the domain defined by the 'problem', and the granting of freedom from specific forms of application, are, as we saw, the main

[16] Obviously, imperfect substitutability also follows from other known dimensions of knowledge, in particular from its tacitness (Polanyi 1966), its distributions among different actors (Weick 1979) and its situatedness (Nelson & Winter 1982: 105).

defining traits of an associational contract. Finally, it is also well known that conditions of radical uncertainty hinder the use of high powered incentives (Milgrom & Roberts 1992) and the specification of performance (McNeil 1978) that are typical of market contracting. Bringing these arguments together we can argue what follows:

Hypothesis 1: Associational contracts will be chosen over bureaucratic contracts, and these over market-like contracts, for transactions involving higher levels of uncertainty.

Interdependence

Interdependence defined on types of asset usage

One definitional trait of alliances is that each participant firm brings assets and capabilities to it. Assets and capabilities can be understood as 'resources', that is, as 'sets of potential services [that] can, in large part, be defined independently of their use' (Penrose, 1959: 25). Due to this independence from specific use, an asset could be employed for its typical services, or, alternatively, as a currency, a medium of exchange (Pfeffer & Salancik 1978). In technology collaborations at least one party's capabilities are used for its characteristic services. We posit that participation of *both* parties as contributors of activities to the R&D project entails a different level of involvement.[17] At a minimum the parties need to verify the compatibility of the activities undertaken, to agree on a schedule for intermediate activities and on specifications of each other's deliverables. In extreme cases, joint action requires mutual adjustments based on real time information that arises from the execution of the tasks. We call these coordination requirements as 'activity-based interdependence' and the case where assets of one party are used just as currencies as 'exchange-based interdependence'. Besides creating a need for procedural coordination, action-based interdependence entails an information exchange that can lessen informational asymmetries

[17] One article that describes and characterizes the content of a business relationship in terms of linking activities is Dubois & Håkansson (1997). According to these authors, links can be characterized in terms of different types, and they give rise to interdependencies.

between the parties (Fama and Jensen 1983), facilitate coordination by direction, and reduce the need to elicit performance through monetary incentives.

The rich control apparatus with which bureaucratic contracts are endowed makes them well equipped to deal with non-trivial degrees of interdependence. By contrast, market-like contracts, which rely mainly on autonomous coordination to the neglect of instruments of conscious adaptation, should be better suited to regulate a flow of goods and services between the parties, than to manage complex problems that are affected by each other's performance. The case for associational contracts is less clear. Locking in resources into an association entails significant opportunity costs, and it does not address directly the problem of interdependence, which calls for coordination mechanisms, rather than simple commitment. Yet such mechanisms could be specified as part of the provisions that complement the associational core of the contract. In sum, we do not expect that the choice between associational contracts and alternative governance forms is clearly determined by activity-based interdependence. For all these reasons we advance the following proposition:

Hypothesis 2: Bureaucratic contracts will be chosen for transactions involving higher levels of activity-based interdependence.

Interdependence defined on technology structure

Even a cursory reading of alliance agreements reveals that the parties possess at least a rudimentary understanding of whether the characteristics of the output envisaged and their respective knowledge bases are such that the production process is neatly decomposable or not.[18] Would knowing as much bear implications for an efficient organizational configuration? A production process where the activities are not technically separable and cannot be carried out in isolation from each other

[18] For instance, in the 1998 alliance agreement between Biosearch Italia S.p.A. and Versicor Inc. of California, parties envisaged the following, neatly separable tasks. Biosearch, was to contribute natural product antibiotic lead compounds. Then Vicuron would apply its skills in combinatorial chemistry, in-vitro assessment of activity, toxicity and pharmacokinetic properties to optimize those leads. Finally, upon detection by Vicuron of promising improved analogues, Biosearch would step in and perform in vivo studies of efficacy. Each stage would end with a rather clearly identifiable intermediate output (Grandori & Furlotti 2007).

without loss of efficiency is called 'team production' (Alchian & Demsetz 1972). Team production gives rise to a metering problem, in the sense that it becomes difficult to establish the proportions in which the output is attributable to each factor. Ambiguity of performance, in turn, makes it difficult to rely on individual incentive rewards and hinders the specific attribution of costs as well. To the extent that each actor is not solely in charge of its own subtask, we aver that team production requires also the formalization of procedures for decision making (Vanberg, 1994). Furthermore, for the same reason, it is likely that the parties will find it more difficult to estimate the time required for completion reliably, and shall envisage the possibility of extending the duration of the alliance. All these features seem to negate as many defining elements of the main dimension market-like contracts are based upon.[19] To be sure, team production is partly unfavorable also to some aspects of bureaucratic contracts but they appear of less fundamental importance. Indeed, Mayer and Bercovitz (2003) observed greater formalization as a means to compensate for a greater expected uncertainty under conditions of task interdependence. All these intuitions lead to the following proposition.

Hypothesis 3: Bureaucratic contracts will be chosen for transactions involving team production.

While a 'community of fate' may have some advantages when it is difficult to measure each other's contributions, cheaper mechanisms for the control of motivational problems are available. For instance, if input factors are rather easily substitutable the parties may count on the threat of dismissal to elicit sufficient performance and may refrain from entertaining too exclusive a relationship.[20] Thus, we treat the comparative assessment of associational and market-like contracting under team production as an empirical question, and we expect the findings to be highly context specific.

Interdependence defined on the scope of activities

[19] In particular, vagueness about termination negates the "sharp in-sharp out" aspect of the contracts supporting market exchange (Macneil 1978).
[20] This corresponds to the case of a team without a central organizing agent (Alchian & Demsetz, 1972: 781).

Alliance scope, in the sense made explicit in Section 0, has been used as a predictor of governance structure by Pisano (1989), Oxley (1997) and Oxley and Sampson (2004). In these studies a wider scope is argued to pose greater contractual hazards (contractibility, spill over), and to call for safeguards in the form of greater hierarchical intensity. Here we rather emphasize the implications of a wider functional scope for interdependence. The addition of manufacturing and sales is not likely to raise the overall task uncertainty substantially. Neither should it pose major challenges to the specification of contractual rights and duties. We posit that the main channel through which a wider functional scope can influence organizational structure is by creating additional and different coordination requirements. For instance, as manufacturing is put under the umbrella of the alliance, things like the timing of the orders, the compliance of the deliverables with quality specifications, and the continuity of supplies become salient. As a result of these conditions of 'sequential interdependence', we expect a greater use of programming (Thompson 1967).

A wider functional scope is likely to compound interdependence with a greater potential for conflict of interests.[21] When the game gets more distributive, the parties will have a stronger incentive to explicitly declaring admissible dimensions for adjustment and setting procedures about it (Williamson 1979). Moreover, the lower cognitive uncertainty of downstream activities means that cost control and time savings become primary ways to add value. As efficiency becomes of greater concern and administrative control better feasible, we expect a greater resort to standardization and more intense monitoring.

All the factors mentioned above seem to indicate that a wider functional span will lead to alliances with more bureaucratic contracts. As to the other alternative contractual forms, we notice on one hand that the type of interdependence that we have just described vastly exceeds the information processing capability of market-like coordination (Thompson 1967, Barzel 1997). Moreover, we

[21] A change in product specifications required at the mass-production stage affects more units of input than changes requested when a product is still at the prototype stage. Moreover, the move from R&D to production is often a move from concepts to artifacts. Thus contingencies arising at the production stage may require changes of materials, which have lower plasticity than concepts, drawings and computer programs.

expect that the resources that are necessary to the performance of downstream activities are more substitutable than those that are required by R&D. Therefore the addition of downstream activities should not translate into stronger incentives to the creation of a long-lasting pooling of resources through associational contracts. Thus we do not expect a significant association of a wider scope with this contractual type. Overall, we advance the following hypothesis:

Hypothesis 4: Bureaucratic contracts will be chosen for transactions involving a wider functional scope

Distribution of knowledge

The knowledge that is necessary to accomplish an R&D project can be distributed between the two parties of an alliance, or it can be concentrated and, in the limit, contributed by just one of them. When one party can contribute R&D competencies and the other has manufacturing and commercialization capabilities, it can also be argued that their knowledge bases are quite differentiated. Therefore, although differentiation and concentration are conceptually different constructs, at least in this stylized sense they overlap considerably.

Several studies have stressed the distribution of the requisite knowledge, and the differentiation of the knowledge bases of the actors, as possible predictors of organizational configurations from the point of view of the effectiveness at problem solving.[22] Burns and Stalker (1961) claimed that when the environment is turbulent firms have to rely on the (decentralized) knowledge of their workers, rather than on know-how embodied in rules and procedures, and the accompanying organizational structure needs to be characterized by intense horizontal relationships, rather than by hierarchy, and by low levels of formalization. For their part, Lawrence and Lorsch (1967: 72) found that influence is more effective at resolving interdepartmental conflict and promoting organizational performance, if it concentrated at the managerial level where knowledge to make decisions is available. In more recent times, the literature on network governance (Jones, Hesterley & Borgatti, 1997) and on the

[22] Pfeffer and Salancik (1978: 50-4) and Hickson, Hinings, Lee, Schneck, & Pennings (1971) have argued the relationship from a power point of view.

new organizational forms (Miles, Snow, Mathews, Miles, & Coleman Jr., 1997) has expressed a similar viewpoint: when the requisite knowledge is distributed, the organizational structure decentralizes and decisions tend to be co-located with knowledge. These hypotheses have been confirmed also at the level of small groups (Rulke & Galaskiewicz, 2000). These arguments lead us to think that distributed knowledge should run counter to the adoption of a centralized, bureaucratic model.

Studies of organizational learning and organizational knowledge have argued that as knowledge differentiation increases so does the diversity in languages, perceptions, practices. Accordingly, knowledge differentiation is expected to increase communication difficulties, to raise the possibility of conflicts of judgments and to reduce the capacity to utilize the knowledge of others (Cohen & Levinthal, 1990). In the inter-organizational field, knowledge differentiation – often labeled 'cognitive distance' (Nooteboom 1998) – has been argued to cause increasing integration difficulties as the 'cognitive distance' between firms grows. These difficulties call for increasingly more powerful knowledge integration mechanisms. However, in the limit the combination of different knowledge bases becomes no longer possible (Becker & Murphy, 1992) and the parties can exchange "the output of the application of knowledge, but not have access to the source" (Grandori, 2001: 391).

In the specific field of R&D biopharmaceutical alliances, when knowledge is concentrated and differentiated because the biotechnology firm possesses all the know-how that is relevant for the 'upstream' research activities, no real transfer of the core technology is possible. The counterparty must be satisfied with receiving the results of the discovery activities. We argue that a rather autonomous, disconnected pattern of decision making, supported by performance incentives is quite suitable for this sequential model of interaction. In other words, we predict that market-like contracting is a suitable governance form in the case of concentrated knowledge and, *a contrario*, that this is not the case with distributed knowledge.

When both parties contribute their capabilities to the R&D *project*, some degree of integration of their knowledge bases cannot be dispensed with. In this case the literature on inter-firm networks indicates that the intense coordination that is required to blend different knowledge bases into an innovative output needs to be sustained by the sharing of risk, responsibilities and benefits as well as by an intense communitarian interaction (Grandori & Neri 1998). Associational contracts provide precisely for all these elements. Combining these arguments we advance the following proposition:

Hypothesis 5: Associational contracts will be chosen over bureaucratic contracts, and these over market-like contracts, for transactions involving an equal distribution of knowledge resources.

EMPIRICAL ANALYSES

Sample and dependent variable

We tested the implications of the arguments above with data that were obtained mainly from the analysis of actual pharmaceutical biotechnology agreements. The contracts have been provided by Recombinant Capital (Recap), a San Francisco Bay area-based consulting firm that manages some of the largest and most detailed biotech business intelligence databases in the world.[23] Our sampling criteria excluded first of all alliances from the initial, 'pioneering', period of biotechnology, when industry participants were building up managerial experience. As biopharmaceutical alliances have become more common, contractual types have become increasingly standardized (Suchman, 1994) and the surviving heterogeneity can be more confidently ascribed to efficiency reasons. Contracts in our sample date from 1989 until 2005. Second, we excluded those alliances where one of the parties was a non-business organization, to avoid introducing excessive heterogeneity. Further, being

[23] In order to take advantage of additional information that Recap collects from the business press, companies' presentations, and various additional sources, as well as to cross-check our own coding of variables with that accomplished by professional contract analysts, we focused on those alliances that have been analyzed in detail by Recap (about 1700, as of Nov 11, 2005) Arguably this biases the sample towards alliances for which a contract is publicly available and for which at the time of analyzing the agreement no problems in the alliance were apparent.

interested primarily in technology cooperation we ruled out those alliances that did not include any element of R&D.[24]

Further, for reasons that will be fully clarified when explaining the operationalization of uncertainty, we stratified our sample so that 'early stage' and 'late stage' alliances would be equally represented.[25] We also left out agreements terminated ahead of time, as a means to bias the sample toward successful alliances.[26] Finally, through random selection we picked the 79 alliance contracts that compose our sample, again with a constraint of approximately equal representation of early stage and late stage alliances. A team of two raters analyzed the contracts during the period from December 2005 to August 2006.

For our sample of pharmaceutical biotechnology alliances the dependent variable (FORM) takes on one of three values, which correspond to the three contractual types that were identified through a preliminary taxonomical analysis. Details of the process that led to the identification of these types are provided in Appendix A.

FORM = 1 for associational agreements

FORM = 2 for bureaucratic agreements

FORM = 3 for market-like contracts

Independent variables

Uncertainty. Radical, non-probabilistic uncertainty is a construct that describes primarily the difficulty of constructing valid models of cause-effect relationships. We claim that in biotechnology research the lack of valid knowledge concerning cause-effect relationships is the more severe, the farther the drug discovery process is from the commercial release. To support our claim we can look at simple statistics of the 'attrition rate' (the number molecules that are discarded during the process) in Table 1.

[24] The selection was based on the value of a measure of contract type coded by Recap's analysts.
[25] By 'early' and 'late', we mean, respectively, alliances entered before and after a lead molecule has been discovered.
[26] While not necessarily the result of governance inadequacy, early termination may be an indication of some unforeseen trouble in the relationship.

Insert Table 1 about here

As suggested by Table 1, this reduction in uncertainty has a monotonic trend that parallels the progression of the development process through the stages that have been codified by regulatory authorities and industry practice. Thus we can think of the stage of research at the time of signing an alliance agreement as a meaningful proxy of uncertainty.[27] Given the profile of the attrition rate, we contend that the identification of a lead candidate implies a dramatic reduction in uncertainty. Thus for our initial analysis we recode Recap's original measure into a three categories variable (STAGE), where the stage of Discovery is treated as a class of its own and is assigned a value of 1, and the remaining stages are evenly subdivided in two classes with value 2 and 3 respectively.[28]

Interdependence defined on type of asset usage. This variable measures whether the contribution of assets to the R&D project by either party is purely financial or whether both are actively engaged in the project.[29] The former type of asset contribution defines an exchange-based interdependence, while the latter is the defining criterion of activity-based interdependence.[30] If not self-evident from task descriptions, active involvement of one party in R&D action was presumed by the observation that that party bears project-related costs.[31] As a result the variable, called ACTIVITY, was coded as follows:

- 0: one side performs R&D activities
- 1: both sides perform R&D activities

[27] A similar operationalization has been used in prior research on biotechnology alliances (Lerner and Merges 1998). The measure we rely upon is the 'stage at signing' as measured by Recombinant Capital (Recap). A detailed description of the measure is provided in Appendix C.
[28] To check for robustness of findings, alternative codifications have also being used.
[29] In principle a party might contribute also assets other than knowledge and finance. In practice, contributions of technical equipment or buildings or similar is never a salient aspect of the contracts in our sample.
[30] Sometimes for confidentiality reasons specific sections are excised from the contracts made available by the SEC to the public. As a result, occasionally the extent of the involvement of a party in R&D activities is somewhat ambiguous. Thus, for practical reasons, it is necessary to assess engagement in action also from the observation of monetary provisions, that reveal whether a given party bears project-related costs (independently of whether they are later reimbursed or not). The monetary arrangements of each alliance are also explicitly analyzed by Recap's analysts, who triangulate contractual content with information acquired by press conferences, company presentations, annual reports, etc.
[31] Project costs were considered distinctly from costs relating to continuous activities like manufacturing or sales.

Interdependence defined on technology structure. This variable measures whether the overall R&D objective of the alliance is neatly decomposable into subgoals that can be pursued by each party in relative isolation; or, conversely, whether the performance by the parties of their respective tasks, requires an extent of collaboration that prevents the possibility of specific, individual attribution of the results of the R&D activities. Since what we are concerned with are the typical expected outcomes of the R&D project, the problem can be reformulated as one of observing whether the alliance may give rise to joint inventions or not. Thus stated, the underlying concept becomes easily observable, as it closely correspond to one of the dominant issues in technology contracting: that of establishing the ownership of foreground intellectual property rights (IPRs). While the particular assignment of rights is a governance variable, the possibility that in a certain alliance the parties develop joint inventions or not is something that depends essentially on the distribution of the requisite capabilities and, relatedly, on the structure of the R&D process.[32] In sum, the variable called TEAM was coded as follows:

- 0: decomposable production (no joint inventions envisaged)
- 1: team production (joint inventions envisaged)

Interdependence defined on the range of functional activities. This variable measures whether an alliance is specifically dedicated to R&D or whether in encompasses also sales and distribution activities.[33] Our requirements for assessing that an alliance has a functional scope that extends to

[32] For instance, in the above-mentioned example of the Biosearch Italia-Vicuron alliance, the process envisaged was one of a neat separation of tasks, to be carried out sequentially on the opposite sides of the Atlantic. All this made the possibility of joint inventions quite unlikely. Indeed the alliance agreement did not envisage any joint invention. Owing to the salience of inventorship and invention ownership Recap's analysis grid has a specific item for that. This allowed us to cross check our assessment with that of Recap's analysts.

[33] While observing such a fundamental characteristic in a generic alliance should pose no problem, in the particular case of pharmaceutical biotechnology agreements this is more complex than it appears. Biopharmaceutical alliance agreements almost invariably regulate the issue of the future stream of continuous rewards associated with the sales of the final product. At least, this is the case in almost 90% of the alliances in our sample. The alternative case, of no envision of continuous rewards, is much rarer (8%) and the case where the client settles the issue with a one-off payment to the R&D firm is almost exceptional (1 observation). Indeed, most contracts contain provisions to the effect that sales rights are assigned and royalty payment obligations are imposed. Since such obligations usually terminate with the later of the expiration of the last valid claim on licensed patents or a predetermined number of years since the start of commercialization (usually 10 or 15), the natural termination date of biopharmaceutical alliance agreements is many years after R&D activities have been completed. However, maintaining that the scope of biotechnology alliances normally extends to downstream activities would be an overstatement. Quite often, after a period of four or five years

downstream activities is that a certain sales activity is a stated goal of the collaboration and, in order to be accomplished, it requires coordination between the parties (or with a joint entity), above and beyond the passive receival of monetary considerations and the performance of activities that are instrumental to that exchange (e.g.: royalty auditing). By applying these criteria to the analysis of contract content we measured the variable SCOPE, coded as follows:

- 0: pure R&D
- 1: mixed activities (R&D and sales)[34]

Distribution of knowledge resources. This variable measures the relative contribution of knowledge resources by the parties to the alliance's R&D project. Contribution of effort and capabilities to regulatory development, manufacturing and sales where not considered. In some cases one party neither takes an active role in the R&D project, nor contributes patents and know-how valuable at that stage of the alliance.[35] In other cases, as in the above mentioned alliance between Biosearch Italia and Vicuron, both parties contribute distinct know how that allows them to be involved in substantial portions of the overall R&D project. Cases like this are coded 'about equal contributions'. The same assessment has been done of alliances in which one party has a lesser involvement in R&D activities but contributes most or all the licenses under the intellectual property and know how that are necessary for the conduct of the R&D project.[36] [37] Intermediate cases (e.g.: where client's involvement in R&D has been quantitatively marginal or has been confined to tasks which had clearly a lower complexity) have been lumped together with those where the R&D firm makes an exclusive contribution. As these assessments involve an element of

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when actual R&D is carried out, only one party – usually the client – become entrusted with all the action rights, and the other becomes a passive receiver of royalty payments, if any.

[34] In order to carry out robustness analyses we tried also alternative coding of SCOPE. In one version 'mixed activities' were defined as 'R&D and manufacturing'; in another, SCOPE was defined as a summated scale of indicators of sales and manufacturing.

[35] This situation is best exemplified by the alliance dated 20 March 1989 between Sumitomo Chemical Company and Regeneron, in which Sumitomo undertook to sponsor Regeneron's general research and development efforts in exchange for a first right of refusal to obtain an exclusive license to products in Japan.

[36] In all the alliances the licensed background rights are explicitly listed in an appendix to the contract.

[37] This consideration of licenses and know-how is what differentiates, also at an operational level, the variable BALANCEKW from the variable ACTIVITY.

subjectivity we cross-checked them with the companies' own representations to the public, as reflected in the press releases collected by Recap, and the two were found to be well aligned.[38] In sum, observations concerning the distribution of knowledge resources are captured by a variable called BALANCEKW that is coded as follows:

- 0: About equal contributions (or minor contribution by R&D firm)
- 1: R&D firm makes dominant or exclusive contribution

Control variables

In addition to the independent variables featured in the hypotheses we also include some control variables that may impact on the contractual choice.

Existing knowledge vs. knowledge to be created.

This variable measures whether the contract stipulates, on top of the R&D collaboration, a transfer or rights on existing technology by means of a license or an option to license.[39] Whenever such transfer is missing we assume that the main purpose of the alliance is to create new knowledge. The reason for being concerned with this variable is that an external observer may misjudge the nature of the alliance: he or she may think the alliance is a genuine collaborative effort, while in reality it could be little more than a transfer of rights, accompanied by ancillary activities. The variable, called EXIST, was coded as follows:

- 0: knowledge to be created
- 1: transfer of existing knowledge

Vertical relationship

[38] The case where the client's contribution could be assessed to be more important than the R&D firm's was observed only once. This case has been initially included in the category "about equal contributions". However it has also been circled for alternative treatment as an outlier.

[39] Possibly as a result of our sample construction we did not observe any outright assignment of existing technology. The transfer of existing technology we are interested in is that for commercial exploitation outside the collaboration. Thus any licensing of rights to develop technology in accordance with a jointly agreed development plan (so called 'background rights') is not considered a transfer of rights on existing technology.

One dummy variable was included to indicate whether the alliance was horizontal (established between biotechnology firms) or vertical (established between a biotechnology and a pharmaceutical firm). This variable can be understood as a crude measure of the difference in the financial strength of the alliance partners, one factor that has been shown to affect rights allocation in biopharmaceutical alliances (Lerner and Merges 1998).

Cross border alliance

Another dummy variable was included to indicate whether one partner in the alliance was from a country other than the US. Although all the contracts were stipulated in the US, the partners to a cross border alliance may have different preferences as to the contractual type, as a consequence of their different institutional backgrounds. In addition, the parties to a cross border alliance may perceive a higher level of contractual hazards due to greater monitoring difficulties and a lower understanding of each other's expectations. Table 2 recaps the measures of all the covariates.

Insert Table 2 about here

Statistical Methodology

We assessed the probability of the choice between the three contractual types with a multinomial logistic regression model. The model is specified as follows:

$$\ln \frac{\Pr(FORM = m \mid \boldsymbol{X})}{\Pr(FORM = b \mid \boldsymbol{X})} = \boldsymbol{X}\beta_{m|b} + \varepsilon \qquad \text{for } m = 1 \text{ to } 3 \qquad (1)$$

where m is the category under assessment, b is the base category, $\boldsymbol{X}$ is the vector of independent and control variables and ε is a random error term. The three possible categories are defined as associational (m = 1), bureaucratic (m = 2) and market-like contractual type (m = 3).

Results

Table 3 presents descriptive statistics and correlations for the variables in our model. In the case of binary variables, the mean also indicates the percentage distribution of cases across the two

categories. Thus, we observe that 65% of the alliances in our database involve activity based interdependence, 78% present team production characteristics and 44% have a wide alliance scope. Overall, conditions of interdependence between the parties obtain rather frequently. On the contrary, only 25% of the alliance in the sample involved a transfer of existing technology for commercial exploitation outside the collaboration. Thus, in most cases, the alliances are likely to have been motivated mainly, if not exclusively, by the express purpose of creating new knowledge. The parties are approximately equal contributors of knowledge resources only in 23% of cases. The mean of VERTICAL indicates that alliances established between biotechnology partners (44%) are only slightly fewer than those established between a pharmaceutical company and a biotechnology firm (56%). Further, our sample sees a dominance of alliances between same-country partners, with cross border alliances being only 39% of the total. [40]

Insert Table 3 about here

As all our dependent variables are categorical, we report polichoric correlations rather than Pearson's. In general the correlations do not show serious problems of multicollinearity. Yet VERTICAL has a considerable association with INTERNATIONAL (.68): most international alliances in our sample are established between pharmaceutical and biotechnology companies. These correlations suggest using Huber-White sandwich estimators of variance.

Insert Table 4 about hereTable 4 presents the results of our multinomial logistic regression analyses. Each model estimates coefficients indicating how covariates affect the choice of associational and bureaucratic contracts relative to the choice of market-like agreements. In all the models after the first, also coefficients for the choice of associational versus bureaucratic contracts are presented. Overall, our hypotheses find good support in the data, but some are rejected.

[40] Our table does not include one obvious control variable: the date of negotiating the alliance. Given the limited size of our sample, and the considerable number of parameters to be estimated, the inclusion of a nearly continuous control variable would have strained the statistical model excessively. Accordingly we assessed the possibility of association between contractual types and the period of agreement in separate cross-tabulation analyses. Contract years have been regrouped together in three categories. One obvious cutpoint was year 2001. For the second cutoff, different years have been selected in the neighborhood of 1994, the year when biotechnology alliances were entering golden era. No alternative grouping has resulted in a significant association between contractual type and year of contracting at the 0.10 level. Data available from the author.

Model 1, which includes only the control variables, has no significant explanatory power as a whole. Of the three control variables, only INTERNATIONAL has statistical significance at the 0.10 level. Model 2 shows the results with the addition of some of the variables of interests. The variable STAGE, the proxy for uncertainty, has three categories. As it cannot be assumed that STAGE is measured at an interval level, we converted STAGE into three dummy variables and entered the first two in the model, leaving the third – the indicator for the Discovery stage – as the reference category. Lower values in the numbers that identify each dummy are to be interpreted as indicators of lower levels of uncertainty. The model as a whole marks an improvement of explanatory power, though the model is significant only at the 0.05 level.

The results in Model 2 indicate that a move from the discovery stage to intermediate stages of the drug discovery process is favorable to the adoption of bureaucratic contracts over market intensive ones. However, as we move further down the drug development process, the impact of lower uncertainty on contractual choices fades away. Thus hypothesis 1 stands only in a certain range of uncertainty. We fail to find support also for the predicted superiority of associational contracts over bureaucratic and market-like ones at higher levels of uncertainty. We shall come again on this later. In Model 2 INTERNATL retains its sign and its significance.

Model 3 adds the full set of the variables of interest. This addition results into a considerable improvement of the predictive power of the model, as reflected in the p value of the chi-square test on the observed log likelihoods. The negative and significant intercepts of equations A and B indicate that in correspondence of zeros of our covariates market-like contracts have higher probabilities of being chosen. All the indicators of higher levels of interdependence (ACTIVITY, TEAM, and SCOPE) are significantly associated – at the 0.05 level or better – with greater use of bureaucratic contracts, in line with our hypotheses 2, 3 and 4. Thus our findings confirm, at the specific level of the contractual choice, what had been found by prior research: that coordination requirements are one important determinant of the choice of governance forms (Gulati and Singh 1998). The model reveals also effects that we did not anticipate. Under conditions of team

production and activity-based interdependence, the attractiveness of bureaucratic contracts increases also vis-à-vis associational contracts. Moreover, a wider functional scope increases the odds of associational contracts being preferred to market-like ones. The configuration of the knowledge resources contributed to the alliance also turns out to be an important predictor of contractual choice. As indicated by the coefficient of BALANCEKW, alliances where knowledge is more distributed among the parties are more likely to favor associational contracts, both over market-like and bureaucratic ones. However, conditions of distributed knowledge do not significantly affect the choice between bureaucratic and market-like contracts. Overall, hypothesis 5 is partially supported. Among the control variables, we observe that in Model 3 INTERNATL loses statistical significance, while the presence of transfers of existing knowledge gives rise to more frequent adoption of associational contracts over the other two alternatives. Finally, in no specification of the model does the circumstance of the alliance being vertical or horizontal significantly impact on the choice of the governance form.

We left considerations on the coefficients of the proxies of uncertainty at the end of the discussion. Upon introducing the remaining variables in the model, the proxies for uncertainty loose statistical significance altogether. There are alternative possible explanations for this fact. As a result of the restrictive criteria that we imposed on our sample, the alliances we observe may not have enough variance in uncertainty. Samples assembled more loosely may exhibit enough uncertainty to show up in statistically significant results, though the challenge of devising valid measures might also increase. A second possibility is that the impact of uncertainty on the choice of contractual form is simply too weak to be detected by statistical analyses carried out on a small sample.[41] A third possibility is that the configuration of knowledge plays a mediating effect between uncertainty and

[41] This explanation carries a certain weight, as prior research conducted on a larger sample has been able to detect a significant impact of uncertainty (operationalized in a quite similar way) on certain important contractual characteristics (Lerner and Merges 1998).

the contractual type.[42] At the moment these are little more than conjectures, which could represent the object of future investigations.

Next we analyze the substantive significance of our results by comparing the discrete changes in the predicted probabilities of the different contractual alternatives for unit changes in our independent variables. Table 5 presents these figures for the five covariates that were found significant in the full model.

Insert Table 5 about here

As shown in the first column of the table, all variables have a considerable impact on the average predicted probability of all three contractual types, and BALANCEKW has the largest impact of all. Conditions of distributed knowledge impact even stronger on the predicted probabilities of associational contracts, which rise by 0.71 over what would be expected under conditions of knowledge concentration. The proxies for interdependence also have a substantial impact on the choice of bureaucratic contracts. Overall, in interfirm alliances the configuration of knowledge resources and the interdependence among the parties are not just statistically significant, but they are fundamental predictors of contractual forms also in substantive terms.

Discrete changes in predicted probabilities do not illuminate the question of how a change in the dependent variables changes the odds of a particular contractual form being chosen relative to another. These questions can be answered by looking at the odds ratios, which can be obtained by exponentiating the base of the natural logarithm by the regression coefficients. After estimating model 3, we calculated the odd ratios of the three contractual types for unit changes of the variables

[42] If this were true we would observe an effect of uncertainty on the configuration of knowledge and on the choice of the contractual type, with the latter disappearing as the balance of knowledge is introduced in the model. The last effect is very clear in Model 3, while a (partial) association between higher uncertainty and bureaucratic contracts has been observed in Model 2. With the current coding of STAGE we are unable to demonstrate a strong association between uncertainty and configuration of knowledge (polychoric correlation is only 0.3 and chi square test is significant only at 0.21 confidence level). However a significant statistical association is found when we use a binary specification of the stage at signing that includes preclinical studies in the 'early' stage, with high uncertainty leading to a concentration of knowledge resources. This may be interpreted in terms of cognitive distance: with tasks characterized by too high levels of epistemic uncertainty, group problem solving (however organized) is hardly possible, and a single actor that masters all the relevant competencies needs to take up the challenge.

of interest that were found to be significant, and we plotted them in Figure 1.[43] The reason for taking an interest in odd ratios is that they help clarifying whether associational contracts can be considered 'intermediate' between the other two contractual types or not. If the 'intermediate' interpretation were justified we would expect that for any given change in contextual variables, the degree to which associational contracts would be found better-matched to a different environment, and thus chosen with increased probability, would be intermediate to the corresponding degrees of the other two archetypical categories. This follows from the fact that, by definition, intermediate governance forms possess, to a lesser extent, the same adaptation mechanisms of more fundamental ones (Williamson 1991). By looking at Figure 1 we notice that a intermediate-like behavior can be seen in the response to activity-based interdependence and team production while this is not true for changes of SCOPE and BALANCEKW. In the latter case the odds ratios of associational contracts lie outside the range defined by the odds ratios of the other contractual forms. Therefore, the interpretation that sees associational agreements as a contractual type that differs 'in kind', rather than an intermediate form, seems justified not only on the basis on their defining elements, but also on account of empirically observed patterns of response to various contingencies.

DISCUSSION AND CONCLUSIONS

This study has investigated the antecedents of alternative contractual types, not treated as points along a continuum of hierarchical intensity. The investigation has been carried out in a context where presumably coordination requirements are a central concern. Indeed, our findings confirm that the variables that measure different types and levels of interdependence are important predictors of contractual form. Our measures of interdependence explain the choice between market-like and bureaucratic contracts. This result echoes the findings of Gulati and Singh (1998) and those of Mayer and Bercovitz (2003) and Mayer and Nickerson (2005). Yet, to our knowledge,

[43] As the regression coefficients of the reference category are zeros, the odd ratios of market-like contracts must be equal to one, which explains why market-like contracts line up over the origin of the axis.

ours is the first study that analyzes the relevance of coordination requirements specifically as a predictor of the choice among alternative contractual forms.

Our findings also confirm that the configuration of knowledge resources do matters, and has the strongest predictive power among those investigated in this paper. In particular, the need to combine complementary knowledge resources impacts heavily on the choice to forge associations. Other studies have focused on knowledge configurations and their relationships with alliance forms (Sampson 2004, Xia Wang 2005). Our findings confirm that this indeed is a useful perspective. However, in these studies technological characteristics were observed at the level of the relationship while we measure them at the level of the transaction. We aver that matching the level between the empirical phenomenon and the empirical variables is more in line with the logic of transaction cost economics. Uncertainty was not found significant in the full model. In general, the effect of uncertainty needs to be investigated more in detail, possibly with larger datasets.

Vis-à-vis certain predictors, associational contracts behave as intermediate forms between market-like and bureaucratic contracts. As this happens in response to constructs for which there is greater wealth of accumulated evidence, we take it as an indirect support to the validity of our dependent variable. Moreover, this indicates that for some practical purposes characterizing contractual forms as points along a continuum is a useful heuristic. However, the behavior of associational contracts vis-à-vis other variables vindicates our choice to treat this governance form as qualitatively different from the two others, more archetypical forms.

This study has limitations. First and foremost, the limited dimension of the sample reduced the power of the tests and did not allow estimating more complex specifications of the model. Second, while emphasizing coordination requirements as a predictor of contractual form, we did not simultaneously test any measure of contractual hazard (except to the extent that interdependence can be described as one type of hazard). Future studies may investigate whether appropriation concerns are still an important predictor of the choice of contractual forms in technology alliances,

once interdependence and the configuration of knowledge resources have been properly controlled for.

Despite these and other limitations, this study has demonstrated that using conceptually-defined contractual types in empirical research is possible and that it can disclose aspects of the governance of interfirm relationships not easily revealed by the use of taxonomies borrowed from practice. Yet, to-date the identification of these types relies on a considerable number of measures that are partly context specific and are not easily implemented in practice. Therefore further progress of this research perspective hinges to a considerable extent on the development of valid and more parsimonious ways to identify conceptually defined contractual forms.

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APPENDIX A

Construction of the dependent variable

The dependent variable FORM is the result of a classificatory study carried out on 79 agreements. Each agreement was coded on 27 items of contractual structure. Measured items included: a) substantive issues, such as arrangements on monetary rewards, property rights and commitments on tasks and resources; b) procedural issues, such as rules for decision making, mechanisms for enforcement, monitoring, coordination, dispute resolution; c) contract-level characteristics, as the length of the contractual document, its duration and the use of state contingent covenants.

Background research for the construction of the coding grid included an extensive review of empirical literature on contracting, review by legal experts and extensive pre-testing. The contracts were coded over a period of eight months by a team of two raters. For most items, Recombinant Capital's analysis grid offered a mean to cross check the raters' own assessment.

Through a principal component analysis of the original variables, three factors loading on 13 items have been identified which, together, accounted for about 55% of total sample variance. The substantive meaning of the factors has been interpreted basing on the factor loadings. Though hardly unequivocal, factor loadings suggested the following labeling and interpretation of the three dimensions:

- *Bureaucratic intensity*: extent to which the contract is articulated, contingencies are explicitly spelled out; control mechanisms and constraints are specified.
- *Associational intensity*: extent of use of cost sharing (as opposed to specific incidence), open ended relationships, low task specification
- *Market intensity*: extent of use of performance incentives and hostages

Through a k-means cluster analysis performed on the scores on these contractual dimensions, three contractual types have been identified. An alternative clustering procedure (TwoStep) yielded the same number of number of groupings suggested by a priori considerations. As shown in the left-hand table below, each contractual type scored high along one dimension (1), was significantly below sample average along a second (-1), and was not significantly different from average along the third (0). Accordingly we interpreted the contractual types in terms of their 'dominant' dimension and labeled them respectively 'associational', 'bureaucratic' and 'market-like'. Cluster memberships provided the three values of the variable FORM.

FINAL CLUSTER CENTERS

	Cluster		
	1	2	3
Bureaucratic intensity	0	1	-1
Associational intensity	1	-1	0
Market intensity	-1	0	1

CLUSTER DISTRIBUTION

Cluster	N	% Cases
1 – Associational	17	22%
2 – Bureaucratic	34	43%
3 – Market-intensive	28	35%
Valid	79	100%

APPENDIX B

A summary of how various studies spell out the constituting elements of 'hierarchy'

Reference	Elements	Comments
Hennart (1988)	Equity investment	The sharing of profits aligns interests. However, Hennart also notices how the pricing of intermediate goods which do not have clear arm's length prices determines how profits are divided between the JV's parent companies, thus often becoming a source of contractual difficulties.
Pisano (1989)	Equity investment, restrictions on rights to sell positions off	In addition to the sharing of profits, equity entails better monitoring opportunities through representation on the partner's board. Agreements on relative contributions are said to be enforceable.
Oxley (1997)	Monitoring, decision and veto rights, sharing of profits, hostages	'Bilateral adaptation', also mentioned, a term which presumably designates things like quantity adjustments, formulaic price adjustments and contingent clauses.
Gulati & Singh (1998)	Monitoring, decision rights, sharing of profits, standard operating procedures, non-market pricing, dispute resolution mechanisms, plans and rules	Emphasis shifted from reward systems to authority ('fiat', 'command structures' and 'hierarchical control' frequently mentioned)
Santoro & McGill (2005)	Hostages, contractual contingencies and ownership	Characterization of hierarchical intensity is not seen as being particularly problematic

APPENDIX C

Definition of alliance stage

	Stage	Definition
1	Discovery	No lead product candidate identified
2	Lead Molecule	Lead product candidate identified but no animal testing yet undertaken
3	Pre-Clinical	Data from animal models obtained, but human trials not yet started
4	Formulation	Research on a vehicle or agent for the administration of a drug
5	Phase I	Human testing focused on safety begun
6	Phase II	Small-scale human testing focused on efficacy begun
7	Phase III	Large-scale human testing focused on efficacy begun
8	BLA/NDA filed	Biological License Application or New Drug Application filed with the FDA
9	Approved	Drug approved for commercialization

TABLE 1

The drug discovery process: length, costs and attrition rates

Molecules entering the phase	Phase		PhRMA 2004 expenditures*	Length (years)
5000-10000	Drug discovery		9.6	5.5
250	Pre-Clinical			1
5	Clinical	Phase I	15.9	1.5
		Phase II		2.0
		Phase III		2.5
	FDA Review		3.4	1.5
1	Large-scale manufacturing			

Adapted from PhRMA (2006), www.bio.org, and Fumero (2003). * Figures in bln USD.

TABLE 2

Constructs operationalization

Construct	Variable	Measure	Values
Uncertainty*	STAGE1	Stage at signing	0; 1: "Late stage"
	STAGE2		0; 1: "Lead molecule to Phase I"
	STAGE3		0; 1: "Discovery"
Type of assets usage	ACTIVITY	Do both parties perform project-related activities?	0: "One side perform activities"; 1: "Both sides perform activities"
Technology structure	TEAM	Do the parties envisage joint inventions?	0: "Decomposable production"; 1: "Team prod."
Functional scope	SCOPE	Just R&D or also sales and/or manufacturing?	0: “Pure R&D”; 1: “mixed activities"
Distribution of knowledge	BALANCEKW	Does R&D firm contribute all the know-how and carries out all project related activities?	0: "R&D firm dominant“; 1: "About equal contribution"
	VERTICAL	Both parties biotech firms?	0: "Biotech-biotech"; 1: "Drug-Biotech"
	INTERNATL	Both parties from same country?	0: "Domestic"; "1: "Cross-border"

*: variable STAGE has been decomposed into the three dummies that were used in the logit models

TABLE 3

Polychoric correlations and descriptive statistics

		1	2	3	4	5	6	7	8	9
1	FORM	1								
2	STAGE	0.13	1							
3	ACTIVITY	-0.28	0.23	1						
4	TEAM	-0.22	-0.04	0.27	1					
5	SCOPE	-0.43	-0.55	0.16	0.50	1				
6	BALANCEKW	-0.54	0.30	0.17	-0.40	-0.02	1			
7	EXIST	0.14	-0.04	-0.44	-0.18	-0.53	-0.53	1		
8	VERTICAL	0.13	-0.05	-0.13	0.12	0.13	-0.44	0.05	1	
9	INTERNATL	0.30	-0.02	-0.22	0.07	0.04	-0.39	0.00	0.68	1
	Obs	79	79	79	77	79	77	77	79	79
	Mean	2.14	2.20	0.65	0.78	0.44	0.23	0.25	0.56	0.39
	Std.Dev.	0.75	0.85	0.48	0.42	0.50	0.43	0.43	0.50	0.49
	Min	1	1	0	0	0	0	0	0	0
	Max	3	3	1	1	1	1	1	1	1

TABLE 4

Contractual form: multinomial logit models

	Model (1)		Model (2)			Model (3)		
	A	**B**	**A**	**B**	**A(B)**	**A**	**B**	**A(B)**
STAGE1			0.54	-0.21	0.75	1.59	-0.26	1.82
			(0.74)	(0.67)	(0.79)	(1.27)	(0.77)	(1.31)
STAGE2			1.44	1.74*	-0.30	2.06	2.16	-0.10
			(0.99)	(0.88)	(0.74)	(2.14)	(2.20)	(1.07)
ACTIVITY						0.92	2.62**	-1.70*
						(0.97)	(1.04)	(0.93)
TEAM						1.47	4.02***	-2.55**
						(1.09)	(1.42)	(1.04)
SCOPE						2.67***	1.94**	0.73
						(1.01)	(0.98)	(0.92)
BALANCEKW						5.00***	2.27	2.73**
						(1.64)	(1.46)	(1.09)
EXIST	-0.47	-0.95	-0.52	-1.02	0.50	2.19**	0.32	1.87*
	(0.72)	(0.65)	(0.76)	(0.69)	(0.74)	(1.09)	(0.94)	(1.01)
VERTICAL	0.00	0.76	-0.14	0.56	-0.70	0.62	1.17	-0.55
	(0.68)	(0.68)	(0.67)	(0.71)	(0.69)	(0.91)	(0.83)	(0.81)
INTERNATL	-1.27*	-0.76	-1.17*	-0.58	-0.59	-1.29	-0.45	-0.84
	(0.70)	(0.68)	(0.66)	(0.70)	(0.71)	(0.90)	(0.82)	(0.79)
Intercept	0.21	0.34	-0.14	0.11	-0.25	-5.81**	-6.90***	1.09
	(0.48)	(0.47)	(0.61)	(0.51)	(0.59)	(2.32)	(2.46)	(1.75)
N	73		73			73		
Log-likelihood	-74.39		-71.03			-47.35		
Chi-square	7.08		19.62			47.21		
P	0.313		0.033			0.000		

Dependent variable is FORM. Base outcome: Market-like. In last column of Models 2 and 3 base outcome is Bureaucratic. Outcomes: A: "Associational"; B: "Bureaucratic"; A(B): "Associational" (compared with "Bureaucratic"). Positive coefficients indicate increased probability that firms select the specified contractual type.

TABLE 5

Marginal effects and economic significance

Change in predicted probabilities as variable increases from 0 to 1 (assessed at 0 of STAGE1, STAGE2, VERTICAL and INTERNATL, and at the mean of the other independent variables)

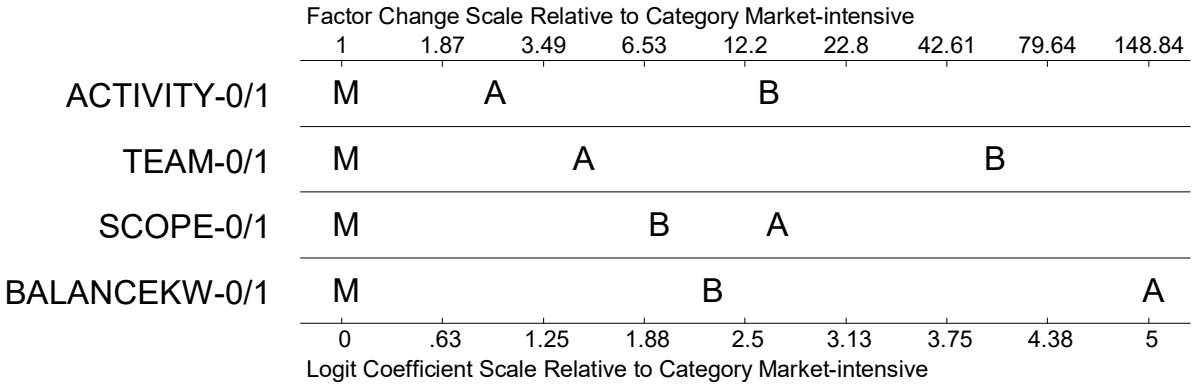
	AvgChg	Associat	Bureaucr	Market-l
ACTIVITY	0.29	0.02	0.42	-0.43
TEAM	0.36	0.07	0.47	-0.53
SCOPE	0.34	0.28	0.23	-0.50
BALANCEKW	0.47	0.71	-0.06	-0.65
EXIST	0.26	0.39	-0.10	-0.29

Baseline probabilities of the dependent variable

	Associat	Bureaucr	Market-l
Pr(y|x)	0.17	0.30	0.53

FIGURE 1

Plot of odds ratios



Odd ratios (a.k.a. “factor change coefficients”): upper scale. A: "Associational"; B: "Bureaucratic"; M: “Market-like”