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

Paper prepared for the International Conference on Economics and Management of Networks (*EMNet*), Rotterdam, 28 – 30 June, 2007

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June 2007

ABSTRACT

Research on interfirm alliances typically analyzes the choice of alliance form as an efficient response to hazards of various kinds. In keeping with this hypothesis alliances are usually ranked along a continuum of 'hierarchical intensity'. However, recent research has emphasized that alliance governance form must also manage coordination requirements. This claim has been tested and corroborated at the level of the choice between major alternative forms, like contractual alliances, minority investments and equity joint ventures (Gulati and Singh 1998). We carry out a similar investigation at the level of the choice between alternative contractual alliances. In addition we allow for the possibility that contracts are multidimensional and differ 'in kind'. Our findings confirm that coordination concerns are an important predictor of the choice between alternative contracts. The distribution of resources has also a significant impact on that choice. The response of different contractual forms to certain predictors contradicts the one-dimensional representation of alliance forms, and implicitly supports the idea that contracts serve other purposes besides providing safeguards against hazards. Finally, the significance of resource-related explanatory variables indicates the need for a more systematic investigation of a resource-base view of contracts.

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

* Mark Edwards made this project possible by allowing very generous access to Recombinant Capital's databases. I thank Eric Brousseau, Anna Grandori, Alberto Monti and Andrea Ordanini for helpful comments. All errors are my own.

1. Introduction

Research on contract choices in interfirm alliances has been mainly influenced by transaction cost economics (henceforth, TCE) (Gulati and Singh 1998). This perspective is primarily "concerned with the *identification, explication, and mitigation of all forms of contractual hazards*" (Williamson, 1996: 5, emphasis in the original). Accordingly, much TCE-inspired research explains the choice of governance forms with the presence of transaction-level hazards.[1]

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 potential conflict, at a minimum 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 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. In particular it decomposes coordination requirements in the various sources they owe to, and examines the power that different types of interdependence in predicting contractual forms. Such decomposition is made necessary by the realization that various forms interdependence can be qualitatively different (Grandori 2001). Further, we examine whether other traditional predictors of inter-firm coordination modes – uncertainty and the distribution of resources – are useful when the explanandum is specifically the formal, enforceable, agreement.

Divergence on the predictors notwithstanding, both the tradition focusing on contractual hazards, and those contributions emphasizing antecedents inspired by organization theory or the resource-based view, 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 and Singh 1998) or 'integration intensity' (Xia Wang 2005). However, prior research (Alter and Hage, 1993; Suchman 1994, Brousseau 1995, Furlotti, 2007) has alerted us that one-dimensional characterizations of inter-firm alliances

[1] "Superior performance is realized by working out a farsighted but incomplete contracting setup in which the object is to use institutions as (cost-effective) instruments for hazard mitigation" (Williamson 1996: 14).

in general, and of alliance agreements in particular, are bound to leave a lot of the observed variance unexplained.[2]

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*. Practically, this requires that contractual forms are not categorized simply by the presence or absence of equity investment (as a proxy of control) or by means of ready-made typologies ('second sourcing', 'licensing', 'technology sharing', etc.) but through an in-depth analysis of structure and process based on theoretically relevant categories. The creation of empirical taxonomies of organizational forms based on an analysis of their elementary building blocks is in the tradition of organizational theory (McKelvey 1982; McKelvey and Aldrich 1983). By carrying out such analysis at the level of formal alliance agreements, and by investigating the antecedents of contractual forms, we bring to bear such tradition on the economic and managerial understanding of inter-firm contracts. Obviously carrying out such task in its entirety exceeds the limits imposed by a single paper. Thus, we take advantage of the results of a prior analysis carried out in Furlotti (2007) and focus here on the predictors of contractual forms.

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 led quite naturally to the choice of biotechnology alliances as the setting of our research.

The paper develops as follows. The next section introduces the results of a study that identified relevant contractual types and the dimensions that define them. Section 3 introduces antecedents inspired by classical organizational thinking. Section 4 develops hypotheses about the relationships between those predictors and different contractual types. Section 5 describes our empirical analyses and their findings. Section 6 discusses the results and concludes.

2. Contractual types

Empirical research on alliance forms has often distinguished alliances based on the presence or absence of shared equity investment (Hennart, 1988; Pisano, Russo, and Teece, 1988; Pisano, 1989; Teece, 1992; Osborn and Baughn 1990; Oxley 1999; Sampson 2004; Oxley and Sampson 2004). Shared equity is generally associated with stronger control and with better incentive alignment, thanks respectively to the administrative apparatus and to the hostage function played by each party's equity share. Other studies expand the types of alliances investigated (Oxley 1997, Gulati and Singh 1998), yet they assume that the

[2] 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.

types considered can be ranked in terms 'hierarchical control', with the equity joint ventures and simple contractual agreements usually situated at the opposite ends of the continuum.[3]

While such representations may be justifiable, given the fact that most of the alliances have focused on agency problems, "the presence of equity sharing also masks difference across each type of structure" (Gulati and Singh 1998: 783) and the same applies to the other particular traits that have been singled out to characterize alliances. That one-dimensional representations are insufficient to describe the variety of interorganizational forms is perfectly clear to anyone who proposed a typology of such forms (Williamson 1991; Alter and Hage 1993; Grandori 1997; Ménard 2004). Empirically, principal component analyses and equivalent techniques reveal that unless two or three dimensions are employed, only a modest fraction of alliance heterogeneity can be explained (Suchman 1994; Garrette and Dussauge 1995; Brousseau 1995; Furlotti 2007).

All these objections notwithstanding, the empirical support for hypotheses that predicate the choice between alliances with different degrees of 'hierarchical intensity' on various types of contractual hazards is fairly strong.[4] Basing on such evidence, contrasting 'market-like' to 'hierarchical' alliances would be a useful heuristic, and it would be justifiable to think of forms that do not fall neatly into either type as 'hybrids'.

However, most of the contractual relations that have been investigated involved the supply of goods or services in exchange for payments (e.g. Joskow 1985, 1987; Masten and Crocker 1985; Crocker and Reynolds 1993; Saussier 2000) or the transfers of rights (in the form of second sourcing, licensing, assembly and buyback, management or marketing service agreements, etc.) rather than genuine joint action collaborations. Thus, arguably, agency concerns are dominant, and the market-hierarchy characterization is satisfactory.

Is an agency framework sufficient also when joint-action alliances are involved? While joint activities are not an exclusive characteristic of R&D alliances, innovation typically requires a combination of different competences and activities (Von Hippel 1998). These combinations, in turn, entail interdependence in various degrees. Further, the innovativeness of outcomes implies the uncertainty of tasks, which compounds with interdependence and renders coordination a non-trivial problem. Thus, R&D collaborations may reveal, better than 'plain-vanilla' alliances, whether a typology based on an agency perspective is fully satisfactory.

From a theoretical point of view, there are good reasons to argue that hierarchy cannot be expected to be a cure for all the situations where market fails. Authority is known to fail under conditions of high uncertainty (Radner 1997). The problem with uncertainty is that it makes difficult to specify what constitutes 'proper' behavior. Setting forth from that reflection, Grandori and Furlotti (2006) argue that under conditions

[3] Representations along a single axis have been adopted also when the characterizing dimension was not the degree of control but 'organizational interdependence' (Contractor and Lorange 1988) the 'degree of vertical integration' (Lorange and Roos 1992), and 'integration intensity' (Xia Wang 2005).

[4] However, David and Han (2004) carried out a systematic investigation of 117 tests of the proposition that as asset specificity increases, hybrids and hierarchies become preferred over markets, and found that only 45% of tests were supported, while 8% of results were counter to the theory.

of radical uncertainty a better strategy than full and detailed contractual specification of actions or the assignment of authority to a single party would be to shift the matter of contracting to something that is capable of generating actions: resource commitments. Obviously a commitment of resources to a joint enterprise would also call for allocations of property rights and for decision procedures on how to make use of pooled resources. Contractual relations defined by these criteria – a pooling of resources and allocations of property rights and decision rights (rather than substantive, detailed prescriptions of tasks) – are certainly not market-like, but neither are they necessarily 'hierarchical'. Thus, the authors design them by a different label, as 'associational contracts'.[5]

Inspired by such considerations, Furlotti (2007) has carried out an empirical investigation of pharmaceutical biotechnology alliances, based on content analysis of their alliance agreements. The analysis grid was developed to gauge the dimensions traditionally identified by the transaction cost perspective, namely the incentive and administrative intensity of contracts. In addition, his measures assessed the extent of specification of task and resource commitments, the assignments of property rights, and the specifications of procedures form decision making. Through a principal component analysis of 27 original variables, three factors have been identified which, together, accounted for about 55% of total sample variance. The defining characteristics of each factor are summarized in Table 1. Basing on factor loadings it is possible to establish a reasonably close correspondence between the three factors and the conceptual dimensions of 'bureaucratic-', 'market-' and 'associational' intensity identified above.[6]

Through a cluster analysis performed on the scores on these contractual dimensions, three contractual types have been identified. As indicated in Table 2, each contractual type scores high along one dimension, is significantly below sample average along a second, and is not significantly different from average along the third. This suggests interpreting the contractual types in terms of their 'dominant' dimension. Accordingly the three types will be indicated as 'associational', 'bureaucratic' and 'market-like' contracts. In the remainder of the paper we shall develop hypotheses on the predictors of these types and we shall test them empirically.

3. Predictors of formal alliance governance

[5] Relations based on 'combinations' of resources and on procedural rules have been identified also by Coleman (1990) and by the constitutional paradigm (see Vanberg 1994).

[6] The first factor seems to capture the intensity of use of formalization and standardization, the overall contractual specification, and the presence of a monitoring apparatus. This is pretty much in line with accounts of organizations developed from Weber's classical bureaucratic model (Hall 1962; Hage 1965; Pugh et al. 1963) which were rather in agreement on at least four dimensions: standardization (uniformity regarding procedures and material), formalization (how far procedures are written down and filed), specialization (number of functions performed by specialists) and centralization (the locus of authority to make decisions). Accordingly, our first factor has been labeled 'bureaucratic intensity'. The second dimension, labeled 'market intensity', measures the extent to which the contract relies on autonomous adaptation through explicit incentives, and de-emphasizes conscious coordination mechanisms. Finally, 'associational intensity' captures that extent to which the contract creates a continuous association of dedicated assets, rather than obliging the parties to the performance of specific behaviour. This is reflected in the choice of sharing as a way to allocate project costs, in the open endedness of the project itself, in the restrained specification of tasks, and in the limited use of contingency clauses as a means to effect adaptation.

What influences the choice of the contractual governance of alliances? As argued above, we are interested in the contractual governance of alliances with significant degrees of joint activity or pooling of resources. Accordingly we are looking for factors that are useful to capture particularly its coordination and integration aspects.

The factors we consider are referable to two fundamental ways of viewing organizations: the first focusing on the task dimensions, the second emphasizing resources.

From the all the variables that have been considered under the first perspective we single out uncertainty and interdependence. The first refers to the extent to which task processes have knowable outcomes (Alter and Hage 1993). This variable has been a factor in organizational theory for a long time (Burns and Stalker 1961, Thompson, 1967) but has not been used frequently as an antecedent of interorganizational configurations. Exceptions were Hladik (1988) and Grandori (1997). However, TCE has reinstated it as a fundamental explanatory variable also at the inter-firm level. The second, interdependence, is an intermediate and composite variable that is often used as a concise predictor of organizational solutions.

A keen concern for resources cannot by credited to a single theoretical perspective. Among the theories that examined organizations in terms of resources there are the resource-dependence theory (Pfeffer and Salancik 1978), the organization assessment perspective (Van de Ven and Ferry 1980) and the theory of negotiation (Grossman and Hart 1986; Hart and Moore 1990). Resources matter in many respects. For instance, in the study of many types of networks it is important to ascertain whether the network receives resources from a single source, like the government, or not. However, given the fact that we are concerned only with dyadic relations between private business organizations, many resource-related variables that have attracted investigation in the past are not relevant in our context. Thus we shall focus only on the extent to which two types of resources – knowledge and the financial resources – are contributed to an alliance by a single party or by both of them.

Below we examine more in detail all these variables, particularly in the context of inter-firm alliances.

Uncertainty

Contracting is supposed to require the specification of actions and/or of goals, particularly in a 'classical' contracting perspective (Macneil 1974).[7] In general uncertainty hinders meaningful specification, that is, the greater the uncertainty, the more detailed specification becomes dysfunctional. This is immediately apparent if the source of uncertainty is the difficulty of identifying all the relevant alternative scenarios or the variability of the factors that may affect the situation, that is, if uncertainty generates *computational complexity* for the decision maker (Simon, 1962, Galbraith 1974). However uncertainty may have other, different reasons. In particular, it may reflect a lack of knowledge of cause-effect relations.

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

Analyzing the type of uncertainty surrounding a given transaction is relevant, as different governance forms are likely to prove effective in dealing with uncertainty of particular kinds.[8]

Interdependence

Interdependence is one of the fundamental explanatory variables in organizational models. Originally interdependence has been investigated in an intra-organizational context (March and Simon, 1958; Thompson, 1967). Later, is has been applied as a predictor of efficient organizational configurations also in inter-organizational settings (e.g. Grandori, 1997). Nevertheless, interdependence is rarely found as a predictor in the literature on inter-firm contracting (Shelanski, Klein 1995; David, Han 2004; Boerner, Macher 2005; Furlotti 2007). Exceptions are Mayer and Bercovitz (2003) and Mayer and Nickerson (2005). Until the work of Gulati and Singh (1998) also the literature on strategic alliances has not used interdependence as an explanatory factor of governance structures frequently.

One reason for this state of things is that most of the contracts that have been investigated involved the supply of goods or services in exchange for payments (e.g. Joskow 1985, 1987; Masten and Crocker 1985; Crocker and Reynolds 1993; Saussier 2000). As a result, the situations they dealt with concerned relatively simple *do ut des* relationships, while interdependence presupposes the division of work and unified effort (March and Simon 1958). By contrast, the parties of an alliance are often requested to perform actions as part of a common effort, not just to supply widgets or commodities. In other words, alliances are frequently based on the division of work and require the diffusion of information and resources, that is, all the basic ingredients of interdependence.

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, rather than being assessed from a retrospective look at past activities.

We posit that depending on some initial conditions relating to the type of assets contributed, to the kind of output envisaged and to the actions undertaken, certain predictable patterns of interaction will ensue. Accordingly, the parties are likely to respond by providing for suitable coordination mechanisms. Not only, but since coordination costs are affected by the structure chosen (Thompson 1967), in principle interdependence might affect also the contractual allocation of decision, action and reward rights.

[8] For instance, to the extent that the sources of uncertainty are of the former kind, letting the future unfold and adapting to it may suffice (Williamson 1975). However, to the extent that uncertainty is 'epistemic', the simple passing of time does not help: what is required is the construction of a valid model of what actions and alternatives are available and what consequences can be expected (Grandori, 2001).

The task of spelling out particular types of interdependence is delegated to Section 4. 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 (Van de Ven and Delbecq, 1974; Dewar and Hage 1978). Task scope is defined as "the degree to which tasks are variable and require a multidisciplinary and multidimensional approach" (Alter and Hage, 1993: 117). "It explains why there is a need for a variety of technologies and a given level of specialization in each of them" (Dewar and Hage 1978: 115). 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. Manufacturing and sales activities clearly require different competences from those that are necessary for R&D. However, they are just instrumental to the overall task and do not increase the "product mix", as sometimes task scope is called. Thus, we investigate scope in the precise sense of the range of functional activities. 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.

Distribution of resources

The concept of 'alliance' entails the notion of collaboration among parties that are peers, in some sense (Oxley and Silverman 2007). In terms of their contributions across the whole spectrum of resources, it is reasonable that the parties establish some form of reciprocity. However, with respect to particular classes of resources quite uneven contributions can be observed. We claim that the degree of concentration of certain resources is an important predictor of certain organizational features of technological alliances. In what follows we focus attention on financial contributions and on the scientific know-how, whether patented or not, brought by the parties to an alliance.

In other settings, it could be argued that the balance of resource contributions is, at least to some extent, endogenous to the relationship. For instance, the willingness of a party to commit capital may be conditional on how much influence the other party is willing to accept. However, managerial literature in general seems to be rather unanimous in treating the balance of resources as an antecedent of certain organizational variables. Additionally, the particular setting of pharmaceutical biotechnology alliances is likely to offer the parties quite few degrees of freedom with regards to choices 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. Similarly, cash-constrained technology start-ups with no products yet in the commercialization stage can hardly be expected to fund the bulk of R&D expenses in projects that often span over a decade or longer.

4. Hypotheses development

4.1. Uncertainty and contractual type

4.1.1. Epistemic uncertainty

In the previous section we have argued that under conditions of epistemic uncertainty simple ex-post adaptation may not be a solution to contracting problems since what is required is rather the construction of a valid model of the world. We posit that at an organizational level, the construction of a valid model benefits from the application of intellectual resources that are sufficient by quantity and related by epistemic domain. This is an almost self-evident proposition that derives from general characteristics of problem solving (Pólya, 1945). The first condition entails that the application of a greater amount of intellectual resources enhances the odds of coming up with a solution. The second one implies that relevant knowledge resources are less than perfectly substitutable. Obviously, imperfect substitutability also follows only from known dimensions of knowledge, in particular from its tacitness (Polanyi 1966, Nonaka and Takeuchi 1995), its distributions among different actors (Weick 1979) and its situatedness (Nelson and Winter 1982: 105?).

From all 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 that provide for the application of a lower amount of resources and structures in which the resources 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 loose the possibility of creating those novel combinations of activities and resources upon which innovation is typically based (von Hippel, 1988). This is a classic proposition in the organizational theory (Burns and Stalker, 1961) that hardly needs further arguing. However, 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 defining traits of an associational contract. Accordingly we can we can advance the following proposition.

> *Proposition 1a: A high level of epistemic uncertainty will be associated with greater use of associational contracts.*

The bureaucratic model is characterized by standardization, formalization, specialization and centralization (Pugh et al. 1963). While specialization need not be in contrast with efficient problem-solving, the remaining characteristics of bureaucracy are difficult to reconcile with the type of uncertainty that surrounds Schumpeterian innovation. Standardization is impracticable by definition when the problem to be solved requires the pursuit of not-previously attempted combinations of activities and resources. Likewise formalization, in the specific sense of a detailed writing and filing of procedures, is unsuitable for handling the explorations that accompany innovative activities.[9] Finally, the concept of 'combination' (of activities and resources; see above) presumes different elements to start with. Typically, in the innovation process

[9] However, a different type of formalization, that fixes the outward form, structure, relationship of elements rather than their content, may be very useful for handling complex problems. One can think for instance of the importance of formal logic or of mathematics for the development of science.

these elements correspond to different knowledge bases, which are the more difficult to master the more they are cognitively distant. In turn, this lack of mastery of the required knowledge is an antecedent that should cause centralized authority to fail (Grandori, 2001). These arguments are not only conceptually plausible, but have received ample support from empirical research that ranges from the seminal work of Burns and Stalker (1961) to the literature on the new organizational forms and network governance (Saxenian 1990, Miles et al. 1997, Jones et al. 1997). To the extent that contracts incorporate bureaucratic elements they are also likely to fail under conditions of epistemic uncertainty. These intuitions lead to the following proposition.

Proposition 1b: A high level of epistemic uncertainty will be associated with lower use of bureaucratic contracts.

What we have called market-like contracts base their governance properties mainly on the self-interest of the parties and on the reduction of the relative importance of conscious coordination mechanisms. More in detail, market-like contracts are characterized by a greater reliance on performance-based rewards rather than on the sharing of residual rewards or on fixed compensation. Further, through the use of hostages these contracts set the proper incentives for contractual performance and reduce the need for alternative administrative ways to safeguard the relationship, like monitoring (Jensen and Meckling 1976). Further, to the extent that they do not require specific commitments of resources, market like contracts are scarcely concerned with the assignment of rights to make decisions over pooled resources, and with the establishment of a centralized authority to prescribe the actions to be taken in the interest of the collaboration.

As argued above, uncertainty hampers the setting of standards. This, in turn, weakens the possibility of measuring performance, which is a precondition for an effective use of incentives (Milgrom and Roberts 1992).

Moreover, as seen before, epistemic uncertainty favors the pooling of knowledge resources, which in turn poses the problem of assigning rights to take decisions concerning their use and the withdrawal from the pool (Vanberg 1994). All this hinders the adoption of market-like governance and suggests the following proposition:

Proposition 1c: A high level of epistemic uncertainty will be associated with lower use of market-like contracts.

4.1.2. Computational complexity: devices vs. abstract knowledge

Biotechnology alliances sometimes concern the development of a device, like a DNA microarray reader, or a needle-free injection system for administering a new drug. In an intuitive sense, the development of a device is even further removed from basic research than the early stages of the drug discovery process. Thus it should involve on average less radical uncertainty. However, ceteris paribus, projects for the development of devices are different from projects based exclusively on chemistry or molecular biology also in another respect: the latter are based mainly on abstract knowledge, whereas the knowledge deployed in projects of the first kind ends up being 'reified' into artifacts. We posit that dealing with devices poses

different contracting problems from dealing with abstract knowledge. First, in comparison with drugs and chemicals in general devices will be cognitively simpler. This means that device producing firms will be under a stronger pressure to resort to alternative means of protecting the competitive advantage, like lead time compression and a quick move down the learning curve. In turn, this implies that in projects for the production of devices efficiency and time management will be more salient concerns. Another difference is that while in the limit a new drug may have at its core just one patent covering a new molecule, devices usually require the integration of several bits of heterogeneous knowledge and overall success may depend heavily on architectural capabilities, above and beyond the individual technologies (Brusoni, Prencipe and Pavitt 2001). This fact coupled with the trend for devices to embody an increasing number of functions, implies that the governance chosen for the development of devices must be equipped to deal with unpredictable variability arising from a high number of elements to be considered, or from a high number of exceptions, that is, with *computational complexity*. The typical organizational response to this type of uncertainty is codification and formalization of information, and ad-hoc residual hierarchical coordination among units (Galbraith 1977, Grandori 1997). With their reliance on the specification of tasks and on the formalization of procedures for control, bureaucratic contracts seem well equipped to deal with this type of uncertainty.

How suitable are the other contractual types in the case of collaborations for the development of devices is less clear. Typically one response to the difficulty to contracting technological information is to bundle it either within less peculiar commodities or within a relationship (Zeckhauser 1996). Thus, the fact that a device realizes such bundling within a physical artifact subtracts from the need to bundle technological information within a relationship. This should favor market contracting and should render associational contracting unnecessary. On the other hand, bringing together the different bits of knowledge that are necessary for the development of a device may be facilitated by an association for one specific order of reasons. In general technological information suffers from problems of counting and valuation (Arrow 1996: 120), which explains why a typical practice for its transmission is barter-like exchange (Zeckhauser 1996). However, an association that is based on the pooling of different technological resources in fact realizes barter and economizes on transaction costs. Yet in turbulent environments the benefits of integration are frequently outweighed by its costs, so that modular architectures often prove superior (Langlois 2007). These considerations may counterbalance each other. In sum, only the following proposition can be confidently advanced:

> *Proposition 2: biotechnology alliances for the production of devices will be more frequently associated with the use of bureaucratic contracts.*

4.2. Interdependence

4.2.1. Interdependence defined on types of asset usage: exchange-based vs. activity-based

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). The parties to an alliance may take advantage of this independence from specific use and employ the asset for at least two qualitatively different purposes. One use is the extraction from an asset of its typical services. Thus a piece of technical equipment may be exploited for the production of the physical goods for which it has been conceived. In this case the asset becomes a factor of production. A different function would be to use an asset as a currency, that is, as a medium of exchange (Pfeffer and Salancik 1978; Allee, 2004). Financial resources are typically used for that purpose, but other assets, like intellectual property or land, could also serve as currencies.

Technology collaborations use at least one party's capabilities for the extraction of its characteristic services. It is not infrequent that the other party's knowledge is leveraged in functions like regulatory development, manufacturing or commercialization. However, with concern to the technological research and development task, one party is often little more than a financier and a bystander. Even as such, that party may be involved in the governance of the project, to determine budgets, supervise progress of activities and take strategic decisions on facts that affect its interests. However, we posit that participation of both parties as contributors of activities to the R&D project entails a different level of involvement.[10] Even in the case where both parties' actions are totally disjoint, the fact that they converge to a common output requires at a minimum a decision about a technical interface and a verification of the compatibility of the activities undertaken. In other cases, the need for coordination will require also agreement on a schedule for intermediate activities and on (possibly flexible) 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 types as 'activity-based interdependence' and the case where assets of one party are used just as currencies as 'exchange-based interdependence'.

The participation of both parties as contributors of activities to the R&D project should have significant organizational consequences. First of all, we expect that action-based interdependence strengthens the need for procedural coordination. Second, the contribution of assets to be employed for their services, rather than as currencies, increases the incommensurability of the parties' resources. This should deemphasize the measurement of both inputs and outcomes, and favors sharing over specific allocation, as a means to distribute the results of the collaboration (Fiske 1992). Finally, the information exchange that accompanies procedural coordination may lessen informational asymmetries between the parties and reduce the need to elicit performance through monetary incentives.

As to our contractual forms, we aver that the sharing of project costs that characterizes associational contracts should be easier to implement where the parties are allowed observe the partner's activities frequently and from close up, rather than where they remain at arms' length. However, such insight into the partner's activities is gained rather naturally when the coordination requirements cause the parties to engage in frequent, 'high-bandwidth' information exchange.

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

By contrast, market-like contracts rely mainly on autonomous coordination and fail to assign even basic decision rights. Overall, this should make them better suited to regulate a flow of goods and services between the parties, carried out within the framework of the contractual 'programme', rather than to manage the solution of complex problems that impinge on each other's performance.

As to bureaucratic contracts the relations they may have with action-based interdependence is rather ambiguous. On one hand being endowed with a rich control apparatus, they seem to be well equipped to deal with non-trivial degrees of interdependence. On the other hand, such apparatus centers on vertical and horizontal and specification of tasks and centralized ad hoc problem solving, which should be prone to failure to govern certain types of joint action interdependence. Thus, activity-based interdependence is unlikely to be a good predictor of bureaucratic contracts. For all these reasons we advance the following propositions.

Proposition 3a: activity-based interdependence will be associated with greater use of associational contracts.

Proposition 3b: activity-based interdependence will be associated with lower use of market-like contracts.

4.2.2. Interdependence defined on technology structure: team production vs. decomposable production

Operationalizing the types of interdependence considered in classical organization theory requires a modicum of understanding of the work flows among the activities involved. At the stage of planning an interfirm technological collaboration even such limited understanding may be lacking for several reasons. First, the relevant activities may take place only several years down the road and the persons that shall be involved may not even be on board for an analyst to ask them. Second, to the extent that the collaboration involves genuine exploration, some activities cannot be meaningfully anticipated. For instance, exploratory biotechnology research is often initiated without clear foresight of specific therapeutic applications (Fumero 2003). As research uncovers promises for a specific disease area the activities that are to be accomplished afterwards get progressively defined. Third, even though the patterns of interdependence can be partially envisaged, they may change during the course the alliance.

Nonetheless, 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. For instance, the contract for a 1998 alliance between Biosearch Italia S.p.A. and Versicor Inc. of California, reveals that the respective specialization of the parties allowed them to envisage a collaboration for the performance of a

neatly separable task.[11] Would knowing as much bear implications for an efficient organizational configuration? We claim that it does, and that it helps predicting the efficient contractual form.

A production process where the activities are not technically separable and cannot be carried out in isolation from each other without loss of efficiency is called team production (Alchian and 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 specification 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.

To be sure, team production is partly unfavorable also to some aspects of bureaucratic contracts. For instance, to the extent that the partner's actions are a source of variability the counterparty's task becomes less specifiable ex ante, at least at an operational level. However, Mayer and Bercovitz (2003) observed greater formalization as a means to compensate for a greater expected uncertainty under conditions of task interdependence. However, this implication seems only of second-order importance, in comparison with the metering problem.

Likewise, we are not persuaded that team production poses enough reasons for associational contracts, although some of the implications of the metering problem are in tune with associational characteristics. While a 'community of fate' may have some advantages when it is difficult to measure each other's contributions, if the input each factor 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.[12]

All these intuitions lead to the following proposition.

Proposition 4: team production will be associated with lower use of market-like contracts.

4.2.3. Interdependence defined on deliverables attributes: existing knowledge vs. knowledge to be created

[11] Biosearch, which had expertise in natural products discovery and in vivo evaluation capabilities, was to contribute natural product antibiotic lead compounds. Then Vicuron would apply its skills in combinatorial chemistry/library synthesis and in 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 and Furlotti 2007).

[12] This corresponds to the case of a team without a central organizing agent discussed by Alchian and Demsetz at page 781 of their 1972 article.

Contracting for information is challenging, as information is an unusual commodity in several ways (Arrow 1996; Zeckhauser 1996). One of the characteristic that most seriously hinders contracting on information is an asymmetric knowledge of value between the buyer and the seller. However, if we focus on that particular bunch of information and knowledge that is technology, we notice that the degree of asymmetry is likely to vary greatly depending on how close a technology is to the stage of practical application. This is rather clearly illustrated precisely by the case of pharmaceutical technologies. When a compound or a protein is in its early stages of development, it has undergone little or no examinations by the regulatory authorities. Similarly, some of the technologies it is based on have not been patented yet. Things like efficacy and long term side effects are understood only partially. Further, the prospects to employ it in the treatment of additional applications are uncertain. From a commercial point of view, it is hard to establish how great an improvement it will represent over competing products. By contrast, as the technology progresses through the development stages not only are valid models of reality built and refined, but knowledge undergoes a massive process of codification.[13] The point is that such codification not only is a reflection of lower uncertainty, but it reduces the asymmetry of information as well. In the limit, a large pharmaceutical company with global distribution may be better positioned to assess the commercial opportunities of a drug in late clinical trials than the specialized biotechnology firm that developed it. In turn, a reduction of asymmetry facilitates contracting and exchanges (Akerlof 1970). Thus we expect that ongoing research and existing research results give rise to quite different contracting problems. In general the latter will offer a more objective basis for the measurement of commercial value, whereas the former requires a bet on the capabilities of the contracting party, on its luck and on its behavioral attitude. The less evaluation becomes problematic the more effective governance through incentives is (Milgrom and Roberts, 1992). Further, codification reduces the need to secure the partner's tacit knowledge to bring the project to completion. Thus, resources need not be firmly locked in. Additionally, the reduction of the hazards of asymmetric information should also, to some extent, dispense from the monitoring apparatus of bureaucratic contracts. To be sure, contracts for the transfer of existing technology often require the selling party to provide assistance and ancillary services, so that at a first analysis they may appear rather similar to contracts for the development of new knowledge.[14] However, if our previous arguments are correct, it would be unwise to pool together in the same contract a transfer of existing research results and a project for the creation of new knowledge. Thus, if any 'projects' are attached to the transfer, they are likely to be of secondary importance, and they should not impact heavily on the governance architecture. All this leads to the following propositions.

[13] The documents that are necessary to obtain FDA approval for a new drug usually reaches a volume of several cubic meters and are composed of millions of pages (Fumero 2003: 155).

[14] A well known example is provided by the Bessemer process for the conversion of crude iron to steel. After licensing the rights on his invention to several manufacturers, Bessemer was forced to refund license fees, due to the inability of the licensees to set up a workable process. Afterwards Bessemer started his own steel works and perfected what turned out to be the most important technique for steel making in the 19th century (Misa, 1995), thus demonstrating both the validity and the incompleteness of the licensed codified knowledge.

Proposition 5a: the transfer of existing technology will be associated with lower use of associational contracts.

Proposition 5b: the transfer of existing technology will be associated with lower use of bureaucratic contracts

Proposition 5c: the transfer of existing technology will be associated with greater use of market-like contracts.

4.2.4. Interdependence defined on the scope of activities

Alliance scope, in the sense made explicit in Section 3, has been used as a predictor of governance structure by Pisano (1989) and Oxley (1997), among else. These authors underscore that a wider alliance scope associates with a greater difficulty in specifying contractual terms, hence with higher contractual hazards. However, it must be noticed that in these studies the comparison is drawn between alliances that focus just on production and marketing and those that carry out also R&D activities. Here we reverse the terms of the comparison, and we ask what difference may ensue from expanding the scope of the activities from just R&D to include also the later stages of the value chain. Thus, we compare 'pure R&D' alliances with 'mixed activity' alliances.

The addition of manufacturing and sales is not likely to raise the uncertainty of the task substantially. Neither is it going to pose major challenges to the specification of contractual rights and duties. We posit that the main channel through which a wider functional scope (as we defined it) 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. These conditions can be described concisely as configuring conditions of 'sequential' interdependence (Thompson 1967). As a result 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. In fact, activities related to the supply of mass-produced products or to sales promotion are likely to have a clearer zero-sum characteristic than R&D. That this must be the case can be easily understood by considering two facts. First 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. Second, 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.

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). Additionally, we expect that in routine activities like manufacturing or sales promotion, declaring such dimensions is cognitively less difficult than for R&D activities. All this should translate into greater use of

presentiation, or explicit planning of adaptation. 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 first of all a more articulated coordination apparatus and a greater reliance on control negate the essence of market-like contracting. Second, we expect that the resources that are necessary to the performance of downstream activities like manufacturing and sales are more substitutable than those that are required by R&D. This implies that the addition of downstream activities does not translate in 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, this discussion allows us to advance the following proposition.

Proposition 6a: mixed activities alliances will be associated with greater use of bureaucratic contracts.

Proposition 6b: mixed activities alliances will be associated with lower use of market-like contracts.

4.3. Distribution of financial resources

Resource dependence theory, argues that exclusive control of a resource, coupled with asymmetry in a relation, is a source of power for the less dependent organization (Pfeffer and Salancik, 1978: 50-4). This applies generically to all types of resources. With regards specifically to financial resources, managerial studies of strategic alliances, have repeatedly found that "equity share is a predictor of the overall control held by the partners of international joint ventures" (Child 2002: 784).[15] Theories rooted in economics have also taken a keen interest in the contributions of financial resources as an antecedent of organizational configuration. For instance, Hart and Moore (1990) predict owners' identity basing on the criticality of the investments.

On these premises, we argue that in technology alliances, a dominant or exclusive contribution of financial resources by one party should be associated with agreements that assign higher levels of control to that party. Accordingly a dominant contribution of financial resources should associate with a lopsided distribution of decision rights and with an administrative apparatus favoring one party. This seems definitely to favor the adoption of bureaucratic contracts. While this could also be argued to run counter to market-like contracting, we have some reservations on this point. In fact, to the extent that knowledge is distributed, and that control is clearly assigned to one party, the relationship may still benefit from the use of performance

[15] Obviously an equity share can be acquired also thanks to contribution of resources of different kind, though financial resources are likely to represent the typical form of contribution.

incentives and the contract may de-emphasize the assignment of particular decision rights. In other words we do not see a clear association between a concentrated contribution of financial resources and the use of market-like contracts, and neither have we envisaged one with the choice of associational contracts.

Proposition 7: in technology alliances, a highly concentrated distribution of the financial resources contributed to the collaboration, will be associated with greater use of bureaucratic contracts.

4.4. Distribution of knowledge

A similar relationship between distribution of resources and efficient organizational structures can be argued to exist when concentration involves knowledge resources. The argument of the resource dependence theory also applies here straightforwardly.

Contingency theory is another stream of literature that sees a relationship between the control of resources and organizational power. In such framework the basis of power is the control of strategic contingencies, which in turn is a latent construct capturing the joint occurrence of several different conditions.[16] The control of resources is likely to confer power through the positive influence it exerts on some of the 'formative indicators' of the latter, notably the effectiveness in coping with contingencies and the centrality of the actor holding the resources (Hickson et al. 1971).

While this is still an application of the logic of bargaining power, other approaches have addressed the issue from the point of view of the effectiveness of knowledge management. One early example in such stream is Burns and Stalker (1961). In their model, 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. In more recent times, the literature on network governance (Jones, Hesterley and Borgatti, 1997) and on the new organizational forms (Miles et al., 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. The performance of groups that have pockets of unique knowledge distributed across different group members is facilitated by flat networks, with minimal hierarchy, that provide opportunities for task related communication and information exchange (Albretcht and Ropp 1984; Rulke and Galaskiewicz, 2000).

Finally, the idea that hierarchy, as a centralized system of decision-making, fails under conditions of distributed knowledge has drawn support also from some economists (Radner 1997).

These arguments lead us to think that distributed knowledge should run counter to the adoption of a centralized, bureaucratic model. As to associational contracts, knowledge concentration renders the holder

[16] In an intraorganizational context "a contingency is a requirement of the activities of one unit which is affected by the activities of another unit" (Hickson et al 1971: 222).

rather self-sufficient and should lessen the need to forge a stable tie-up with complementary knowledge. Thus, we can argue *a contrario* that distributed knowledge favors such association. Finally, we fail to see a significant influence of knowledge distribution on market-like contracts. In sum, all the preceding discussion can be condensed in the following propositions:

Proposition 8a: in technology alliances, distributed knowledge resources will be associated with a higher use of associational contracts.

Proposition 8b: in technology alliances, distributed knowledge resources will be associated with a lower use of bureaucratic contracts.

For the reader's convenience Table 5 in the Appendix summarizes the hypotheses developed so far.

5. Empirical analysis

5.1. Sample and dependent variable

We tested the implications of the arguments above with data that were obtained mainly from the coding 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. As of October 23, 2006 Recap's databases contain 23,687 high-level summaries of biotech alliances commenced since 1973. 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 coding of variables with that accomplished by professional contract analysts, we focused on those alliances that have been analyzed in detail by Recap. [17] 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 chinks in the alliance were apparent.

Our sampling criteria excluded first of all those alliances where one of the parties was a non-business organization, in the belief that that might introduce excessive heterogeneity in the sample. Second, being interested primarily to technology cooperation we excluded those alliances that did not include any element of R&D, and focused exclusively on the granting of licenses, production, marketing, the setting of standards, the assignment of assets or options, etc. The selection was based on the value of a measure of contract type coded by Recap's analysts. We excluded also alliances where both parties were pharmaceutical companies. While it might be interesting to investigate whether industry membership made a difference in terms of alliance governance, these alliances were numerically too few to expect statistical significance.

At the next step (for reasons that will be explained in Section 5.2), we assessed that we would like to have both 'early stage' and 'late stage' alliances equally represented in our sample. By 'early' and 'late', we mean an alliance entered before or after a lead molecule has been discovered. Then through random choice we selected a total 280 alliances stratified in such way that each class encompassed 50% of the alliances. At this stage we noticed that Recap's database offered us a coarse but convenient means to bias the sample

[17] As of Nov 11, 2005 they were about 1700.

toward successful alliances. In fact, it contains a flag to identify those alliances that were terminated ahead of time. While not necessarily the result of governance inadequacy, early termination may be an indication of some unforeseen trouble in the relationship. This allowed us to exclude an additional 40 alliances. 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, as discussed above

FORM = 1 for associational agreements

FORM = 2 for bureaucratic agreements

FORM = 3 for market-like contracts

Although different forms are represented by different natural numbers, we do not treat FORM as an ordinal variable.

5.2. Independent variables

Epistemic uncertainty. Epistemic uncertainty is a construct that describes primarily the difficulty of constructing valid models of cause-effect relationships, but it may also include other related sources of incomplete knowledge, notably lack of clarity of preferences and difficulty of observability. We claim that in biotechnology research the lack of valid knowledge concerning cause-effect relationships is the more severe, the farther is the drug discovery process 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 3 in the Appendix. At the discovery stage, biotechnology firms begin with a hunch about molecules (or proteins, or monoclonal antibodies) that may be effective vis-à-vis a certain target. As knowledge of actual cause-effect relationship is very vague, the search has to encompass thousands of molecules. As the research progresses through successive stages, many molecules are rules out. Moreover, researchers begin to characterize progressively better those that are left and establish properties like pharmacological potency, toxicity, the pharmacokinetic and pharmacodynamic profiles, etc. As suggested by Table 3, this reduction in uncertainty has a monotonic development 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. The measure we rely upon is the 'stage at signing' as measured by Recombinant Capital (Recap). A detailed description of the measure is contained in Table 4. Given the profile of the attrition rate, we assume 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.

Computational complexity: abstract knowledge vs. devices. This variable measures whether the purpose of the alliance was for the development of abstract knowledge or for the production of knowledge reified into artifacts. This variable was operationalized by asking whether the alliance was for the production of a device or just a therapeutic agent (a molecule, a protein, or a monoclonal antibody). Although the end product for the development of a drug often includes formulations of a drug substance, if the 'reification' does not go any further we assessed that the project is for the production of abstract knowledge. On the contrary, when physical and spatial organization of chemical compounds is an important feature of the product, we classify the knowledge developed as reified.[18] Whether the product is a device or not is usually made explicit in the Definitions section of biotechnology agreement, which normally defines the product in a distinct clause.[19] The variable, called DEVICE, was coded as follows:

- 1: immaterial deliverables
- 2: technology devices.

Interdependence defined on type of asset usage: exchange-based vs. activity-based. This variable measures whether the contribution of assets to the R&D project by either party is purely financial or whether both contribute to the project with their own capabilities, thus becoming actively engaged in the project.[20] The former type of asset contribution defines an exchange-based interdependence, while the latter is the defining criterion of activity-based interdependence. 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 easier to assess engagement in action 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. 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.[21] As a result the variable, called ACTIVITY, was coded as follows:

- 1: exchange-based interdependence

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[18] This is the case, when the object of the alliance is the supply of compound libraries, that is, samples of structurally related chemical compounds arranged in a format such as a microtiter screening plate, with evenly spaced wells containing compounds in specified amounts.

[19] A typical clause defining a therapeutic agent reads as follows: "1.2 COLLABORATION PRODUCT shall mean any product incorporating or derived from any peptide or antibody compound, and the sequence contained therein, discovered by DYAX using the DYAX TECHNOLOGY during the COLLABORATION TERM, and that binds to an HGS TARGET" (Collaboration and license agreement between Human Genome Sciences, Inc. and Dyax Corp., dated March 17th, 2000). In the case of alliances for the production of devices the corresponding clause reads as follows: "2.22 'Products' shall mean the HP System, HP Software, MTX Chips, MTX Software and Necessary Reagents" (Collaboration agreement between Hewlett-Packard Company and Affymetrix, Inc., dated Novembre 11, 1994.).

[20] 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.

[21] Project costs were considered distinctly from costs relating to continuous activities like manufacturing or sales promotion.

- 2: activity based-interdependence

Interdependence defined on technology structure: team production vs. decomposable production. 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. 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.[22] 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. In sum, the variable called TEAM was coded as follows:

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

Interdependence defined on deliverables attributes: existing knowledge vs. knowledge to be created. This variable measures whether the contract stipulates a transfer or rights on existing technology or not, by means of a license or an option to license.[23] The transfer of existing technology we are concerned about 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. Whenever such transfer is missing we assume that the main purpose of the alliance is to create new knowledge.[24] The variable, called EXIST, was coded as follows:

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

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.

[22] In that agreement the term "joint inventions" is used to indicate inventions to be put to use in the geographic territory that has been reserved for joint commercial exploitation. Thus, it is not related with the originator of an invention.
[23] We did not observe any outright assignment of existing technology.
[24] Such assumption is warranted by the criteria of sample construction that excluded those alliances that did not include any element of R&D, and focused exclusively on the granting of licenses, production, marketing, the setting of standards, the assignment of assets or options, etc.

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.[25] Our requirements for assessing that an alliance has a functional scope that extends to 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:

- 1: pure R&D
- 2: mixed activities (R&D and sales)[26]

Distribution of financial resources. This variable measures the relative contribution of financial resources that arises as a consequence of the explicit financial commitments of the parties and of the tasks they are required to accomplish within the framework of the collaboration. For the measurement of this variable it is not sufficient to look at the first component, since it is not infrequent the case of one party (or both) undertaking obligations to perform costly activities for which no corresponding compensation is established. For instance, in the above mentioned alliance between Biosearch Italia and Vicuron, the agreement did not provide any monetary compensation for Vicuron's compound optimization activities nor for the in-vivo studies to be conducted by Biosearch Italia. A case like this was coded "approximately equal contributions". An opposite case is represented by the alliance established in September 1989 between Immulogic and Merck, centered on recombinant DNA technologies for the treatment of autoimmune diseases. Here Merck reserved for itself all the tasks from preclinical research until mass production and commercial exploitation, and agreed to fully compensate Immulogic for the performance of research at the discovery stage. This case was coded "Client makes exclusive contribution". Besides these polar situations we observed cases where the client made a dominant, yet not exclusive contribution, either because reimbursement of project costs to the R&D firm was partial or because the R&D firm was allowed to

[25] 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). This holds true also for alliances entered at the discovery stage, for which commercialization is, on average, 14 years away from the signing of contract (PhRMA 2006). Indeed, most contracts contain provisions to the effect that manufacturing 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 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.

[26] 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.

participate with a junior position in downstream functional activities, like sales promotion, at its own cost.[27] However, as excessive dispersion of cases would violate conditions for application of chi-square tests, we classified dominant contributions together with cases of exclusive contribution. Only two cases in which the financial contributions of the R&D firm exceed those of the client were observed. These cases stand out also for several other unusual contractual characteristics. Thus, although they have been initially treated as cases of about equal financial contributions, we also controlled whether treating them as outliers would significantly impact on results. In sum, observations concerning the distribution of financial resources are captured by a variable called BALANCEFIN that is coded as follows:

- 1: About equal contributions (or no significant contribution by client)
- 2: Client dominant or exclusive

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 extreme cases the client is purely a financier and does not take active part in R&D. 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. 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.[28] Intermediate cases (e.g.: where client's involvement in R&D has been quantitatively marginal or has been confined to tasks which had a clear lower complexity) have been lumped together with those where the R&D firm makes an exclusive contribution.[29] As these assessments involve an element of subjectivity we cross checked them with the companies' own representations to the public, as reflected in the press releases collected by Recap. Only one case was observed where the client's contribution was assessed to be more important than the R&D firm's contribution. This case has been initially included in the category "about equal contributions", based on the presumption that it would sort the same consequences. However it has also been circled for alternative treatment as an outlier.[30] In sum, observations concerning the distribution of knowledge resources are captured by a variable called BALANCEKW that is coded as follows:

[27] Given the salience of cost allocations within alliance agreements, Recap's analysis grid has an item called "Reimbursement basis" that usually distinguishes partial from total reimbursements and helped us cross checking our own assessment.
[28] In all the alliances the licensed background rights are explicitly listed in an appendix to the contract.
[29] An example of engagement in lower complexity activities is given by the alliance dated Nov 1997 between Signal Pharmaceuticals and Serono, where the R&D firm was entrusted with target identification and validation, high throughput screening and lead optimization, while the client was assigned more routine pre-clinical and clinical development.
[30] This case coincides with one of the two outlier candidates discussed with the variable BALANCEFIN.

- 1: About equal contributions (or no significant contribution by R&D firm)
- 2: R&D dominant or exclusive

Table 6 in the Appendix contains value labels and descriptive statistics for all variables.

5.3. Statistical Methodology

The fact that our dependent variable is categorical, severely limits the types of statistical methods that can be adopted to test our hypotheses. Discriminant analysis and logistic regression are the appropriate statistic techniques for the prediction of the category in which an object is located. However the former is not able to accommodate categorical predictors. The alternative methodology, logistic regression, is quite popular in studies focusing on the choice of alternative governance forms. However, unlike OLS regression, logistic regression derives parameters through maximum likelihood estimation. As MLE relies on large sample asymptotic normality, when observations are few compared to the number of independent variables one may get high standard errors. Our case, where sample size is 79 and the total number of independent variables and control variables is ten, does not attain the minimum advisable ratio observations / parameter (Peduzzi et al. 1996). Therefore we opt to analyze our dataset through cross tabulations and related statistics of association. In particular, we shall assess whether a pair of variables are independent through Pearson's chi-square statistics. Since our dependent variable has no meaningful ordering, we must use a measure of nominal association. Among several available alternatives we opt for the Uncertainty Coefficient (Theil 1972) which expresses the percent reduction in error in accounting for the variance in the dependent variable. Chi-square only tells us whether there is a significant association overall between the two variables investigated while the Uncertainty Coefficient provides us a measure of the strength of the association. However, to test our hypotheses we must be able to tell whether the observed frequency in *particular* cells is significantly different from the expected frequency, and which is the sign of the difference between the two values. One suitable test is given by the Adjusted Standardized Residual, which is defined as follows:

Adjusted Standardized Residual =

[(Observed Cell Count - Expected Value) / √ (Expected Value)] / estimated Standard Error

Adjusted Standardized Residuals (henceforth: adj. res.) are distributed according to a Standard Normal distribution (Haberman 1978), thus values above 1.96 or below -1.96 indicate significant differences at the 0.05 level.

5.4. Crosstabulation analyses

The results of our crosstabulation analyses are summarized in Table 7. We notice, first of all, that STAGE has a significant association with the choice of governance form (p= 0.067) level and helps reducing the error in the prediction of FORM by 5.7%. No significant association is found with associational contracts (hypothesis 1a not supported). On the contrary, partially in contrast to propositions 1b and 1c, we observe a significant increase of bureaucratic contracts and a significant drop of market-like ones only in intermediate stages of the R&D process (adj. res. are 2.6 and -2.6 respectively). These are not easily explainable results.

From the results of further tabulations (available from the author), it appears that the 'Discovery' stage is a class in its own, which witnesses a certain dominance of market-like contracts (44.7%). Most of these alliances (71.1%) are of the research-for-fee type, where just one party contributes to research results. If we analyze the other two stages separately, we notice that the results significantly support the proposition that greater uncertainty reduces market-like contracting. Greater uncertainty also increases bureaucratic contracting (proposition 1b rejected).

DEVICE is significantly associated with contractual form at the 0.01 level. However the cross tabulation of DEVICE violates the condition for Chi-square significance test that fewer than 25% of cells have a minimum expected count lower than 5. Moreover, the fact that the minimum expected frequency has a rather extreme value of 2.8 discourages even the use of more robust tests like the likelihood-ratio. Together with the size of the whole sample, a particularly uneven split of the variable (83.5% Immaterial deliverables, 16.5% Technology devices) is also jointly responsible for this situation. Thus we assess that our sample does not justify discussing the results of the cross tabulation for this variable.

ACTIVITY has a significant association with contractual type. Knowing whether the type of asset usage defines an exchange-based interdependence or an activity based interdependence helps reducing the error in accounting for the variance in the dependent variable by 10.5%. By looking at the cross tabulation we observe that activity-based interdependence is associated with a substantial decrease of market-like contracting, while it causes a sharp rise in the use of bureaucratic contracts and not in associational contracts, as it was expected. These differences are significant (adj. res. = -3.5 and 3.8 respectively). This provides clear support for proposition 3b but not for 3a.

TEAM turns out to be another useful predictor of contractual form. Knowing whether technology is decomposable or not helps reducing the error in variance by almost 10%. In particular team production associates with use of market like contracts significantly below sample average (adj. res: -3.1), and with greater resort to bureaucratic governance (adj. res: 3.6). The first finding provides support for proposition 4. Associational contracts do not vary significantly with technology structure.

EXIST shows no significant association with the contractual type. Thus the fact a R&D collaboration agreement also stipulates a transfer or rights on existing technology or not, is not a significant predictor of the type of contractual governance adopted. Propositions 5a, 5b and 5c are not supported. Conceptually, whether an alliance is created for the purpose of developing new knowledge or just to transfer rights on research results should be a fundamental difference, with the potential to impact on the contractual form. The fact that we failed to find support for that hypothesis may indicate that the simultaneous presence within an agreement of both types of transaction does not pose particular problems: the governance apparatus established to manage the development of new knowledge can effectively manage also an exchange of existing one. In turn, this could indicate either that it is possible to design contracts in a modular way, or that the contractual relation that is established to develop new knowledge is enough of a hostage for the exchange transaction, and provides sufficient safeguard despite suboptimal governance. A stronger test of hypotheses

5a, 5b and 5c would require including both 'pure' license agreements and pure collaboration agreements in the sample, but we have ruled that out by conscious design.

SCOPE significantly affects contractual form, and shows an uncertainty coefficient of 0.078. As proposed by proposition 6a, R&D alliances that encompass sales activities adopt bureaucratic contracts significantly more often than sample average (adj. res.: 2.3; Proposition 6a supported). The idea that a wider functional scope also decreases market-like governance (Proposition 6b) finds strong support in our data, (adj. res.: -3.5), while associational contract are invariant to functional scope. These findings are fairly robust to alternative operationalizations of SCOPE.[31]

BALANCEFIN is significant at the 0.001 level and helps improving prediction of the dependent variable by 8.3%. Counter to proposition 7, greater concentration of financial resources does not lead to a significant increase of bureaucratic contracts. On the contrary, it has a significant effect of market-like and associational contracts; the former increase, and the latter decrease when financial contributions are more unbalanced. These results are not significantly altered by the exclusion of two potential outliers mentioned in Section 5.2.[32]

BALANCEKW is significant at the 0.001 level and helps reducing the error in accounting for FORM by 8.4%. The use of bureaucratic contracts does not associate significantly with the distribution of knowledge (Proposition 8b not supported), while the use of associational contracts does (adj res. -3.9; proposition 8a supported): associational contracts are more likely to be observed under conditions of distributed knowledge. Finally, market-like contracts are not significantly affected by this variable. These results are not significantly altered by the exclusion of one potential outlier mentioned in Section 5.2.[33]

5.5. Logistic regression

As discussed in Section 5.3, data limitations have prevented the application of logistic regression to the testing of our hypotheses. However, this technique can further extend our understanding of the antecedents of contractual forms if we turn to an exploratory mode. The findings of the previous analyses help fulfilling the data requirements of logistic regressions in two ways. First they screen out two measures of interdependence – EXIST and DEVICE – that have no explanatory power or suffer from other limitations. Second, they indicate that market-like contracts are somewhat easier to predict than the other two contractual forms. Thus, rather then undertaking the quite ambitious task of predicting three different contractual forms, we can focus on discovering which variables help predicting the use of forms alternative to market-like contracting. This halves the number of parameters to be estimated and eases data requirements considerably.

[31] The sign of the relationship with market-like and bureaucratic contracts does not change when a wider functional scope is operationalized as a summated scale of the indicator for 'manufacturing' and the indicator for 'sales', although the effect on bureaucratic governance is significant at a level slightly lower than 0.05 (adj. res. 1.8). In other words, manufacturing seems to dilute the predictive power of SCOPE. One possible explanation for this result could be that even 'pure R&D' alliances very often have to manage manufacturing for use in clinical trials (not measured). Thus, to some extent they are already equipped to deal with manufacturing in general, so that the shift from clinical trial to large scale manufacturing does not make a radical impact on governance forms.

[32] Data available from the author.

[33] Data available from the author.

Accordingly we recode FORM into the binary variable FORM2. Since our purpose is exploratory, we can use a stepwise logistic regression with forward selection of variables based on the likelihood ratio test. Table 8 reports the results of this exercise. The chi-square for the model is significant, which indicates that the fit is satisfactory. The model predicts actual contractual form in 81.1% of cases, which represents a 16.5% increase in accuracy over assigning all the contracts to the non market-like category (64.6%). To interpret the results it must be borne in mind that for the purpose of the analysis the independent variables have been recoded, so that regression results are contrasted to the lower original values of ACTIVITY, TEAM and SCOPE, and to the final values of STAGE, BALANCEFIN, and BALANCEKW. Thus the estimated parameters reflect the change in the probability of observing nonmarket-like contracts associated with higher levels of interdependence and uncertainty, and with more evenly balanced distributions of resources. The stepwise process, with entry probability at 0.05, selects four variables (ACTIVITY, TEAM, SCOPE and BALANCEFIN). The positive signs of the coefficient indicate that the odds of choosing a nonmarket-like contract increase with higher levels of interdependence and with a more balanced distribution of financial resources. Thus most of the variables that had been found significant in crosstabulation analyses retain predictive power also in the logistic regression. Moreover, the direction of all the relations is coherent with those that were found in crosstabulation. Thus, for instance, predictors of market contracts confirmed as significant in crosstabulations turn out to be – with reversed sign – logistic regression predictors of nonmarket-like. Judging on the size of the odd rations (column 'Exp(B)' in Table 8), the distribution of resources contributes the most to explaining the probability of non-market contracts, followed by the structure of the technology.

Two variables, the proxies for uncertainty and for the distribution of knowledge lose explanatory power when other predictors are controlled for. With reference to the latter we observe that if BALANCEFIN is removed from the analysis, BALANCEKW becomes significant ($p<0.05$) and its coefficient retains the same sign and approximately the same size of the coefficient for BALANCEFIN.[34] This is an indication that the two variables behave pretty much in the same way. Indeed a cross tabulation of the two variables reveals a significant association between them, with a concentrated contribution of knowledge corresponding to a concentrated contribution of financial resources (see Table 9). Indeed, as a look at Table 9 also reveals, almost three fourths of the alliances in our sample can be described as research-for-fee alliances, since in these cases the concentration of knowledge resources is the mirror image of financial resources.

With regards to STAGE, we observe from Table 8 that while as a whole its effect on the dependent variable is not significant, the second category of STAGE has a positive significant coefficient ($p<0.10$), while the first category does not. This indicates that in comparison with late stages, the increase in uncertainty associated with intermediate stages raises the probability of observing non-market contracting, while a move to the discovery stage does not, as already observed in crosstabulation analysis. Since the possibility that very late stage alliances have the same effect on non-market contracting as discovery stage

[34] Data available from the author.

ones is conceptually quite disturbing, we investigated whether any variable may shade the impact of uncertainty, as observed with the distribution of resources. A cross tabulation of STAGE with the other variables, reveals that STAGE is significantly associated with SCOPE. In other words, 'Discovery' alliances are predominantly also 'pure R&D' alliances, while 'Late stage' ones are also 'Mixed activities' alliances. If we repeat the stepwise logistic regression while omitting SCOPE, STAGE fails again to make it among the significant variable, though by a narrow margin ($p = .12$). However, both of its categories become significant at the .10 level and with the expected sign.[35]

6. Discussion and conclusions

This study has investigated the antecedents of alternative contractual types, not treated as points along a continuum of hierarchical intensity but as qualitatively different forms. 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, for the most part, important predictors of contractual form. Our measures of interdependence explain the choice between market-like and bureaucratic contracts. This result is perfectly aligned with the findings of Gulati and Singh (1998) and with those of Mayer and Bercovitz (2003) and Mayer and Nickerson (2005), though the latter two studies interpreted interdependence as one particular form of contractual hazard, rather than as a source of coordination requirements. Uncertainty also turned out to have some explanatory power. This is broadly in like with the predictions of TCE. However, the impact we found is not linear: a higher uncertainty favors initially bureaucratic contracts but at higher levels the choice reverts to market like contracting. While this effect needs to be investigated more in detail, it is possible that at very high levels of uncertainty client firms give up their attempts to control the alliance through bureaucratic means, and consider the alliance as a simple purchase of an option on research results, possibly trusting other means, like the differentiation of their alliance portfolio, to safeguard against risks. This is remindful of the finding by Poppo and Zenger (2002) who argued their data suggested that managers may lose confidence in complex contracts as uncertainty becomes very severe.

Our findings also confirm that variables emphasized by negotiation theory, the resource dependence theory and the knowledge-based view – distributions of resources – do matter, and have the strongest predictive power among those investigated in this paper. In particular, the need to combine complementary resources impacts heavily on the choice to forge associations, that is, on the choice to commit resources firmly, while loosely specifying particular behaviour. This finding is supportive of a resource-based view of contracts.

Vis-à-vis several predictors, market-like and bureaucratic contracts behave in a specular way and associational contracts behave as hybrids, in the sense that they are rather insensitive to contingencies that cause bureaucratic contracts to move in one direction and market-like contracts to move in the opposite one.

[35] Data available from the author.

This is indirect evidence of the face validity of our labeling of the contractual forms. Moreover, this indicates that for many practical purposes characterizing contractual forms as points along a continuum is not terribly off the mark. However, vis-à-vis the distribution of resources associational contracts behave in a distinctly different way from the other two contractual forms, and this vindicates our choice to treat governance forms as qualitatively different.

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, we emphasized coordination requirements as a predictor of contractual form. However, we did not 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 the inclusion of appropriation concerns affects the choice of contractual forms in general, and of associational contracts in particular. One puzzling findings of our study is that associational contracts are observed at all levels of task uncertainty. As this type of contracts seems to arise mainly in response to the need of combining resources, this indicates that tight combinations of resources may be an efficient governance form even at moderate levels of epistemic uncertainty. While transaction cost economists may immediately think of contractual hazards as a possible explanation, this fact would not square well with the loose specification of actions and with the lean control apparatus of associational contracts. Indeed, this is a puzzle that awaits further investigation.

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Appendix

Table 1 – Contractual dimensions

Bureaucratic intensity	Detailed contract specification Monitoring rights Bureaucratic control through budgets Behavioral vetoes High use of contingency clauses
Associational intensity	Open endedness Low task specification Sharing of costs Low use of contingency clauses
Market intensity	High use of explicit incentives High use of contractual hostages Low resort to cost sharing Close ended projects Low assignment of decision rights Low specification of resources

Table 2 Contractual types

	Contractual type		
	1	*2*	*3*
Bureaucratic intensity	0	1	-1
Associational intensity	1	-1	0
Market intensity	-1	0	1

Notice: '1' and '-1' indicate values of the corresponding variable that are respectively significantly above and below the sample average. '0' indicates values that are not significantly different from sample average. By construction it is not possible that all cluster score high or low along a single dimension

Table 3- The drug discovery process: length, costs and attrition rates

Molecules entering the phase	Phase		PhRMA 2004 expenditures (bln USD)	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)

Table 4 - 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 therapeutic agent
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 5 - Summary of hypotheses

Hypothesis	Independent construct	Sign of association	Contractual form
1a	*Epistemic uncertainty*	+	*A*
1b		-	*B*
1c		-	*M*
2	*Computational complexity*	+	*B*
3a	*Activity-based interdependence*	+	*A*
3b		-	*M*
4	*Team production*	-	*M*
5a	*Transfer of existing technology*	-	*A*
5b		-	*B*
5c		+	*M*
6a	*Wider functional scope*	+	*B*
6b		-	*M*
7	*Concentration of financial resources*	+	*B*
8a	*Distribution of knowledge*	+	*A*
8b		-	*B*

NS: not significant association; “A”: associational; “B”: bureaucratic; “M”: market-like

Table 6 – Value labels and descriptive statistics

Variable	*Value*	*Label*	*N*	*Min*	*Max*	*Mean*	*Std. Dev.*
Dependent variables							
FORM	1	"Associational"	79	1	3	2.1	0.75
	2	"Bureaucratic"					
	3	"Market-like"					
FORM2	0	"Market-like"	79	0	1	0.2	0.41
	1	"Nonmarket-like"					
Independent variables							
STAGE	1	"Discovery"	79	1	2	1.5	0.50
	2	"Lead molecule to Phase I"					
	3	"Late stage"					
DEVICE	1	"Immaterial deliverables"	79	1	2	1.2	0.37
	2	"Technology devices"					
ACTIVITY	1	"Exchange-based interdependence"	79	1	2	1.6	0.48
	2	"Activity based interdependence"					
TEAM	1	"Decomposable production"	77	1	2	1.8	0.42
	2	"Team production"					
EXIST	1	"Knowledge to be created"	77	1	2	1.2	0.43
	2	"Transfer of existing knowledge"					
SCOPE	1	"Pure R&D"	79	1	2	1.4	0.50
	2	"Mixed activities"					
BALANCEFIN	1	"Equal"	77	1	2	1.8	0.40
	2	"Client dominant"					
BALANCEKW	1	"Equal"	77	1	2	1.8	0.43
	2	"R&D firm dominant"					

Table 7 – Cross tabulations, chi-squares and measures of nominal association

			FORM			Tot.	χ^2	Asymp. Sig.	Expected count < 5	Uncert. Coeff.	Asymp. Sig.
			Associational	Bureaucratic	Market-intensive						
STAGE	1	%	41.2%	41.2%	60.7%	48.1%	8.78	0.07	2 cells (22.2%)	0.057	0.034
		Adj. Res.	-0.6	-1.1	1.7						
	2	%	23.5%	38.2% *	7.1% *	24.1%					
		Adj. Res.	-0.1	2.6	-2.6						
	3	%	35.3%	20.6%	32.1%	27.8%					
		Adj. Res.	0.8	-1.3	0.6						
Total		Count	17	34	28	79					
DEVICE	1	%	64.7%	97.1%	78.6%	83.5%	9.41	0.01	2 cells (33.3%)	0.062	0.034
		Adj. Res.	-2.4	2.8	-0.9						
	2	%	35.3%	2.9%	21.4%	16.5%					
		Adj. Res.	2.4	-2.8	0.9						
Total		Count	17	34	28	79					
ACTIVITY	1	%	41.2%	11.8% *	60.7% *	35.4%	16.39	0.00	0 cells (.0%)	0.105	0.046
		Adj. Res.	0.6	-3.8	3.5						
	2	%	58.8%	88.2% *	39.3% *	64.6%					
		Adj. Res.	-0.6	3.8	-3.5						
Total		Count	17	34	28	79					
TEAM	1	%	29.4%	2.9% *	42.3% *	22.1%	13.95	0.00	1 cells (16.7%)	0.099	0.042
		Adj. Res.	0.8	-3.6	3.1						
	2	%	70.6%	97.1% *	57.7% *	77.9%					
		Adj. Res.	-0.8	3.6	-3.1						
Total		Count	17	34	26	77					
EXIST	1	%	76.5%	84.4%	64.3%	75.3%	3.26	0.20	1 cells (16.7%)	0.02	0.022
		Adj. Res.	0.1	1.6	-1.7						
	2	%	23.5%	15.6%	35.7%	24.7%					
		Adj. Res.	-0.1	-1.6	1.7						
Total		Count	17	32	28	77					
SCOPE	1	%	41.2%	41.2% *	82.1% *	55.7%	12.29	0.00	0 cells (.0%)	0.078	0.04
		Adj. Res.	-1.4	-2.3	3.5						
	2	%	58.8%	58.8% *	17.9% *	44.3%					
		Adj. Res.	1.4	2.3	-3.5						
Total		Count	17	34	28	79					
BALANCE-FIN	1	%	50% *	17.6%	3.7% *	19.5%	13.86	0.00	1 cells (16.7%)	0.083	0.042
		Adj. Res.	3.5	-0.4	-2.6						
	2	%	50% *	82.4%	96.3% *	80.5%					
		Adj. Res.	-3.5	0.4	2.6						
Total		Count	16	34	27	77					
BALANCE-KW	1	%	58.8% *	15.2%	11.1%	23.4%	15.44	0.00	1 cells (16.7%)	0.084	0.045
		Adj. Res.	3.9	-1.5	-1.9						
	2	%	41.2% *	84.8%	88.9%	76.6%					
		Adj. Res.	-3.9	1.5	1.9						
Total		Count	17	33	27	77					

Notes: dependent variable: FORM; *: significant at the 0.05 level or better

Table 8 – Logistic regression – Results of forward selection

Variables in the equation

Variable	B	S.E.	Wald	df	Sig.	Exp(B)
ACTIVITY	1.36	0.64	4.51	1	0.03	3.89
TEAM	2.41	1.13	4.58	1	0.03	11.12
SCOPE	1.36	0.68	4.04	1	0.04	3.90
BALANCEFIN	3.40	1.50	5.11	1	0.02	29.95
Constant	-3.01	1.12	7.15	1	0.01	0.05
-2 log likelihood	63.19					
Chi-square	31.47				0.00	
% correct	81.1%					

Dependent variable: FORM2
ACTIVITY entered on step 1; SCOPE, on step 2; BALANCEFIN2, on step 3; TEAM, on step 4.

Variables not in the Equation

Variable	Score	df	Sig.
STAGE2	2.97	2	.226
STAGE2(1)	1.39	1	.239
STAGE2(2)	2.95	1	.086
BALANCEKW	1.11	1	.293
Overall Statistics	4.07	3	0.254

Table 9 – BALANCEKW * BALANCEFIN Crosstabulation

			BALANCEFIN		
			1 Equal	2 Client dominant	Total
BALANCEKW	1 Equal	Count	11	6	17
		%	73.3	9.8	22.4
	2 R&D firm dominant	Count	4	55	59
		%	26.7	90.2	77.6
Total		Count	15	61	76
		%	100	100	100

Chi-square: 27.95 ($p < 0.01$); Cramer's V: 0.61 ($p < 0.01$).