Appropriability Hazards and Governance in Strategic Alliances: A Transaction Cost Approach

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Despite the recent proliferation of interfirm alliances designed to govern cooperative efforts in creating or exploiting technology, we have limited understanding of how firms choose among the various alliance types available to them. In this article, I examine the governance properties of different alliance types and develop a simplified market-hierarchy continuum of alliances. This then forms the basis for an empirical examination of appropriability hazards and governance. Strong support for hypotheses derived from transaction cost theory is provided by analysis of a large sample of interfirm alliances. More hierarchical alliances are chosen when appropriability hazards are severe because technology is difficult to specify or because the scope of activities is wider, so that monitoring is hampered.

1. Introduction

A key argument in transaction cost economics (TCE) is that transactions are aligned with governance structures so as to effect a discriminating—mainly transaction cost economizing—match (Williamson, 1991). The archetypal problem in TCE is the vertical integration or "make versus buy" decision, and the focus of transaction cost economizing in this context is on mitigation of "hold-up" problems associated with investments in specific assets (Klein et al., 1978; Williamson, 1985). However, this asset specificity condition is only one example (albeit a significant one) of a more general class of contractual hazards. Indeed, in his most recent discussion of the TCE agenda, Williamson (1996:3) suggests that "identification, explication and mitigation of contractual hazards—which take many forms, many of which long went unremarked—are central to the exercise."

Many thanks for guidance and suggestions go to Oliver Williamson, David Mowery, Bronwyn Hall, Pablo Spiller, Nick Argyres, Emerson Tiller, Francine Lafontaine, Scott Masten, Bernard Yeung, the editors and anonymous reviewers at JLEO, and participants in the seminars and workshops where earlier versions of this article were presented. Research support was generously provided by a Bradley Fellowship through the Center for Research in Management at the University of California, Berkeley and by the Orel Crawford Foundation.

This article examines a form of contractual hazards that previously has been underdeveloped in transaction cost theory—that is hazards related to weak property rights, as they apply to transactions involving technology transfer within interfirm alliances. Many present-day "strategic alliances" are designed to govern cooperative efforts in the creation or exploitation of technology (Hagedoorn, 1993) and firms establishing such alliances must beware the potential for leakage of valuable intellectual property (Teece, 1986). Although these so-called appropriability hazards are a well-accepted characteristic of technology contracts (Levin et al., 1987) there has been little systematic examination of how appropriability hazards can be mitigated within different types of interfirm alliance.

As the number of interfirm strategic alliances exploded in the 1980s, so variety in the types of organizational form adopted grew apace. In addition to equity joint ventures, interfirm linkages run the gamut from fairly simple technology licensing contracts to joint marketing agreements, technology sharing arrangements, research corporations, and consortia. Nonetheless, most previous empirical research has focused only on the choice between contract-based and equity joint ventures (Gulati, 1995; Pisano, 1989, 1990; Pisano et al., 1988), finding that equity arrangements are favored when contracting hazards related to small-numbers bargaining and uncertainty are present to a significant degree.[1]

Although there have been previous attempts to provide useful taxonomies of the large variety of interfirm alliances (e.g., Contractor and Lorange, 1988; Lorange and Roos, 1992), a need remains for a model of interfirm alliances that is tightly connected to underlying theoretical constructs. A contribution of this article is to undertake a closer examination of the governance properties of different alliance types and so provide a systematic way to differentiate among them. A simplified market-hierarchy continuum of alliance forms is proposed which then forms the basis for an empirical analysis of appropriability hazards and governance mode choice.

In choosing among different interfirm alliance types, the logic of transaction cost economics suggests that more "hierarchical" alliances will be chosen for transactions where contracting hazards are more severe. In conducting empirical work we need to maintain the transaction as the unit of analysis, describe transaction characteristics associated with elevated hazards in the particular operational setting, and develop hypotheses that describe how these hazards are mitigated in alliances in the market-hierarchy continuum. In the analysis reported here, the focus is therefore on transaction attributes that determine the level of appropriability hazards, and hence the preferred governance mode,

1. In his later article examining the choice between in-house and external sources of R&D, Pisano discusses transaction costs stemming from both small-numbers bargaining and appropriability concerns (Pisano, 1990). However, as the focus is on leakage to unrelated third parties, the only measure of appropriability hazards used is the number of established companies attempting to develop or commercialize products in the relevant technical area, aggregated over the entire world market.

in technology transfer alliances. Partner firms in such alliances may choose between a unilateral contract (e.g. a simple license), a bilateral contract (such as a cross-license or technology sharing agreement), or an equity joint venture. These alliance forms are ordered along the market-hierarchy continuum with equity joint ventures having governance attributes closest to those of internal organization.

Hypotheses for the empirical study are derived by tracing the source of contracting hazards that arise when firms attempt to transfer technology via a simple unilateral contract. These "appropriability hazards" can be traced to difficulties in adequately specifying payoff-relevant activities, monitoring the execution of prescribed activities, and/or enforcing contracts through the courts. Results from empirical analysis of samples of alliances drawn from the Cooperative Agreement and Technology Indicators (CATI) database provide strong support for the transaction cost hypotheses: more hierarchical alliances are chosen when property rights associated with the technology are difficult to specify in a contract and when the scope of activities is wider, so that monitoring of activities is hampered.

Inclusion of firm-level variables in the empirical model also illuminates a source of confusion in previous empirical studies: In the international management literature, empirical studies of governance choice in inter-firm alliances increasingly rely on the logic of transaction cost economics (e.g., Agarwal and Ramaswami, 1992; Gomes-Casseres, 1989; Hennart, 1991a; Hladik, 1985), but almost without exception, these studies use firm-level characteristics (R&D spending, advertising, firm size, etc.) to proxy for the transaction-level characteristics featured in TCE. This mismatch between the underlying phenomenon and the empirical measures is reflected in inconsistencies in the observed effects of firm-level variables in these previous studies.[2] In the empirical analysis reported here, firm-level effects do not have statistically significant effects. This confirms that, in line with transaction cost theory, it is the attributes of the transaction (i.e., the project), and not those of the firm as a whole, that determine the more efficient mode of governance in alliances.

The remainder of the article is structured as follows: the theoretical framework is presented in Section 2, in which the market-hierarchy continuum of interfirm alliances is introduced, and in Section 3, where appropriability hazards are discussed and the hypotheses are developed. Section 4 details the empirical analysis. Results are presented and discussed in Section 5. Section 6 concludes.

2. The Market-Hierarchy Continuum of Interfirm Alliances

Interfirm alliances for the creation or exploitation of technology come in many varieties. Examples include licensing, cross-licensing and technology sharing

2. Studies of international business arrangements have focused primarily on the choice between autonomous investment and joint venturing. For a discussion of inconsistencies in the observed effects of some of these firm level variables on the propensity to invest autonomously, see Gomes-Casseres (1989).

agreements, international production joint ventures, collaborations in product and process R&D (ranging from R&D contracts to equity joint ventures), and customer-supplier partnerships. The transaction cost view of an interfirm alliance is that of a hybrid governance form, lying between the polar forms of market (i.e., arms-length "spot" contracts) and hierarchy (i.e., organization within the firm). As such, hybrids retain some of the incentive characteristics of markets, while allowing enhanced monitoring and bilateral adaptation. Although these latter governance features are not as well-developed as in the hierarchical governance mode, organizing a transaction within a hybrid avoids some of the bureaucratic and shirking costs associated with hierarchy (Williamson, 1991).

Prior research on interfirm alliances has focused attention on one "hybrid archetype," the equity joint venture (e.g., Geringer and Hebert, 1989; Gomes-Casseres, 1989; Harrigan, 1986; Hennart, 1991b; Killing, 1983; Pisano et al., 1988). This is the classic form of hybrid organization, involving the creation of a new entity jointly owned and operated by two or more collaborating firms. In governance terms, the shared equity in the new venture operates as an effective hostage exchange: because the value of the joint venture depends critically on continued operation, each firm effectively posts a bond equal to its equity share, the value of which is at best only partially redeemable should operations cease. Furthermore, the ongoing returns to each partner are based on the profits of the venture as a whole (usually with distributions in proportion to equity shares), so that the incentives of the "parent" firms are more closely aligned than in the case of an arms-length transaction.

Although the intensity of incentives in a joint venture is not reduced to the same extent as in a fully integrated structure (since parties to the transaction retain a degree of autonomy), the attenuation in incentives nonetheless requires that other administrative controls take the place of the "discipline of the market." These administrative controls include a board of directors, typically comprising members from partner firms in proportion to equity holdings. This provides a direct communication link with senior management of the parent companies, facilitating superior monitoring of partner firms' activities (Kogut, 1988). Furthermore, joint venture owners may be legally entitled to independently verified financial information in addition to information acquired through direct observation (Osborn and Baughn, 1990:505). However, in contrast to directives from senior management or the board of directors in a fully integrated firm, the directives from joint venture parent companies are subject to negotiation and compromise if conflicts between the goals and interests of the firms arise. Indeed, the right of veto over strategic decisions is often explicitly incorporated in the formal agreement accompanying the creation of a joint venture (Geringer and Hebert, 1989; Killing, 1983).

These "veto rights" and other contractual features of joint venture agreements may suggest that the contract law supports of this governance structure approach those of the classical contract law of market transactions (Macneil, 1978). However, because of the need for continued cooperation within the joint venture, the rigid blueprint of classical contract law is rarely applied, and instead is replaced by the highly adjustable framework of "neoclassical" or "relational" contracting, where third-party arbitration may be called for under certain circumstances but access to the courts is reserved as a forum of ultimate appeal (Llewellyn, 1931; Williamson, 1985:70–72).

A simple extension of the transaction cost logic suggests that the many other types of interfirm alliance could be "ranked" by their relative governance attributes, based on the instruments just described—incentive intensity, administrative controls, and contract supports—so rendering the choice of alliance form conceptually straightforward and susceptible to empirical examination using statistical methods. However, any attempt to develop an exhaustive ranking soon runs into significant operational obstacles (see, e.g., Contractor and Lorange, 1988; Lorange and Roos, 1992).[3]

First among these operational difficulties is the extent of microanalytic data required: Making fine-grained assessments of the governance attributes of a particular alliance requires information on a long "list" of features, including formal and informal monitoring or reporting requirements, provisions for third-party arbitration, details of assignments of managerial control rights, and the extent of effective hostage exchanges built into the agreement. Moreover, even with all the necessary data in hand, it is not clear how we compare two alliances in which different combinations of these various governance instruments are present. And finally, different hybrid organizations are often designed to govern quite different types of activities. As such, they may embody idiosyncratic governance features that are as much a feature of the activity itself as a feature of the governance structure per se. This is particularly true in technology sharing or research and development, for example, where pooling of technical resources may have inherent hostage features.

Perhaps as a result of the confusing array of potential combinations of governance instruments available, reported alliance forms tend to cluster into discrete groups, within which there is undoubtedly significant variation, but for which we can identify "step function" differences in governance attributes so that we can assign an ordinal ranking to the alternatives. This allows us to construct a market-hierarchy ordering of organizational forms, with the caveat that we only attempt a ranking of governance structures within broadly comparable activity classes.[4] From available descriptions of technology-related alliance

3. In their original continuum, Contractor and Lorange (1988) rank cooperative ventures from least to most hierarchical, based on the degree of "organizational interdependence," as follows: technical training and start-up assistance; production, assembly and buy-back agreements; patent licensing; franchising; know-how licensing; management or marketing service agreement; nonequity cooperative agreements in R&D, development, or coproduction; equity joint venture. However, in later work, Lorange and Roos (1992) back away from this detailed ordering and present a simplified continuum based on the "degree of vertical integration." The definitions of organizational forms in this new continuum are not entirely transparent and it is not clear how this new continuum maps into the previous one.

4. In the empirical study below, we therefore restrict our attention to horizontal technology transfer arrangements which do not have a significant R&D component.

forms, we can identify three such governance categories (going from least to most hierarchical):

- Unilateral contractual agreements (e.g., unilateral licensing agreements, long-term supply contracts, R&D contracts)
- Bilateral contractual agreements (e.g., technology sharing or cross-licensing agreements, joint research agreements)
- Equity-based alliances (i.e., joint ventures and research corporations)

For the two contract-based hybrid forms, the key distinguishing governance feature is greater incentive alignment in bilateral contractual agreements, based on the ability to effect in-kind hostage exchanges. The variety of administrative controls and monitoring rights found in equity joint ventures, along with the further increase in incentive alignment achieved via shared equity, mean that equity joint ventures lie closest to the hierarchy end of this "market-hierarchy continuum" of alliance forms.

3. Appropriability Hazards in the Market for Know-How: Implications for Governance of Interfirm Alliances

The contracting concern in technology transfer alliances is essentially that pay-off relevant activities sometimes cannot be fully specified in a contract, or that prescribed activities cannot be adequately monitored or enforced. When contracts are incomplete because of gaps in specification, the possibility of moral hazard arises on either side of the transaction. For example, the holder of the technology may later find a better partner and so deliver less (or inferior) technology to its partner than promised in the original agreement. On the other hand, the recipient firm may use or modify the technology in ways that were not intended in the contract and which are injurious to the transferor.[5] These are the so-called appropriability hazards associated with technology contracts, the sources of which are rooted in the need to transfer poorly defined tacit "know-how." The transaction-level features leading to elevated appropriability hazards, and their operational corollaries, are explored and summarized in the hypotheses developed below, but first we look at how appropriability hazards may be mitigated within the alliance forms in the market-hierarchy continuum.

A central tenet of TCE is that, absent significant contracting hazards, the "default" low-cost governance mechanism is a simple unilateral contract (Williamson, 1991:279). However, where characteristics of the transaction are such that full specification of the assets to be transferred is infeasible, or monitoring is incomplete, employing a unilateral contract for technology transfer is problematic since either party has incentives to act opportunistically (as suggested above), potentially leading to extensive ex post haggling or complete failure of the agreement. The power of the courts to redress these failures will also be limited, given the associated difficulties of third-party verification.

5. I am indebted to Tracy Lewis for suggesting this framing of the problem.

Foreseeing such problems, both parties to the transaction have incentives to mitigate against the contracting hazards by "moving up" the market-hierarchy continuum of alliance forms.[6] If ex post contract disturbances are not expected to be too severe, then a bilateral contract may suffice: the in-kind hostages inherent in such an arrangement mean that both parties have a continued interest in the maintenance of the arrangement, and ex post haggling will be reduced as a consequence. Furthermore, if disturbances are correlated (e.g., if unexpected external events can be expected to impact the value of the two firms' technology holdings in a similar direction), then monitoring problems are mitigated and opportunities for ex post haggling are further reduced. Nonetheless, defection from the spirit of the contract is likely in the event of highly consequential disturbances. In this instance, the parties are again faced with the problem of resolving disputes in court in the face of difficult third-party verifiability issues. Thus, where severe appropriability hazards are anticipated, a move to an equity joint venture structure is warranted: here the shared equity, additional monitoring rights, and administrative controls make the structure more responsive to even quite large disturbances, and only under extreme "end-game" circumstances will an appeal to third-party adjudication be required.

To understand the governance implications of a particular set of technology transfer activities within an alliance, we now examine, in greater detail, the special contracting problems encountered in such transactions. Appropriability hazards arise out of the unique trading characteristics of information and the consequent failures in the market for "know-how," important aspects of which are captured in Arrow's "fundamental paradox" of information (Arrow, 1971:152)—that the value to the purchaser is not known until he has the information, but then he has in effect acquired it without cost. This paradox provides the rationale for systems of intellectual property protection which exist in various forms throughout the world. Nonetheless, as previous research has amply demonstrated (Levin et al., 1987; Mansfield, 1985, 1986), firms and industries differ significantly in their propensity to patent industrial innovations, as well as in how rapidly new technological information leaks out to rival firms.

Although often characterized as such, it is apparent that "technology" is not synonymous with pure "information," nor does it always share the same public good features as information.[7] Arguments in the literature on interfirm technology transfer, for example, rest on the notion that technology is a complex mix of codified data and poorly defined, tacit "know-how." (Mowery and Rosenberg, 1989:7). This literature emphasizes the difficulties encountered by firms when they try to acquire technology via an arms-length contract because the tacit know-how involved is, by definition, extremely difficult to transfer without intimate personal contact, involving teaching, demonstration, and participation (Polanyi, 1962). In this view, the advantages of hierarchy in reducing the costs

6. Although this discussion is couched in terms of a bilateral transaction, the logic applies equally to a multilateral situation.

7. See Nelson (1990) for an insightful review of the treatment of technological know-how in the economics literature.

of technology transfer hinge on communication, organizational routines, and a necessity for prolonged colocation of participants (Kogut, 1988).[8]

A potential source of confusion concerning the effects of tacit know-how on governance comes from earlier discussions of "appropriability regimes" that refer to leakage of information leading to imitation by rivals (Teece, 1986). There it was argued that a high degree of tacitness in the know-how embodied in a technological innovation reduces appropriability hazards, because inventing around a patent is more difficult in that case (Teece, 1986:287). However, if we consider the effect of tacit know-how on the ease of contracting, it is apparent that the argument does not carry through: if parties attempt to contract for the right to use a technological asset embodying significant tacit know-how, they will face difficulties in adequately specifying the asset and associated property or usage rights to be transferred in a contract. Thus, while the tacitness of know-how reduces appropriability hazards with respect to unrelated parties, hazards in contracting for the transfer of the asset are nonetheless increased.

At the most basic level, if the purpose of a contract (or alliance) is the creation rather than exploitation of technology, adequate specification of property rights will inevitably be problematic, since the contracted assets do not exist at the time the contract is written, and technological innovation is a highly uncertain process (Freeman, 1982; Mowery & Rosenberg, 1989). Even for existing technology, specification is not necessarily straightforward. In addition to the level of tacitness, which may vary across technologies, the age of the technology may be a factor; a contract is more difficult to specify for a novel technology because the buyer and seller share less of the tacit know-how associated with its application than is usual for more "routine" technology transfers (Davidson and McFetridge, 1984).

While it is very difficult to obtain data on aspects of technology transferred in interfirm alliances such as "tacitness" or age, it is possible to make inferences about associated contract specification difficulties based on the type of activities involved in an alliance. For example, in the sample of interfirm alliances used in the empirical analysis described below, alliances may involve the transfer of existing technology to facilitate production and marketing activities in the alliance. Alternatively, product (or process) design activities may be carried out within the alliance, or there may be a mixture of design and production activities. Of these different "transaction types," those which include design activities are most likely to involve the creation or significant modification of technology, so raising the difficulty of adequate specification of

8. Previous empirical studies (Behrman & Wallender, 1976; Robinson, 1988; Teece, 1977) identified several factors that increase the costs of interfirm technology transfer, including the complexity and age of the technology, the recipient firm's "absorptive capacity" (Cohen & Levinthal, 1990), and the amount of previous technology transfer experience. These studies stress the consequent increased need for training, and personnel transfers, but several of these factors also increase contracting hazards associated with transfer—thus the challenge facing firms in such a transaction is to physically organize the project in such a way as to allow effective transfer of the technology while simultaneously designing the governance structure to mitigate associated contractual hazards.

contractual terms. Alliances involving these activities are therefore predicted to present greater appropriability hazards than are "pure" production and marketing agreements, and hence the adoption of a more hierarchical governance structure is hypothesized, ceteris paribus.

Observation 1. A more hierarchical governance mode will be chosen when an alliance involves product or process design than when only production or marketing activities are undertaken.

The amount of monitoring required for partner firms to have confidence that prescribed activities are indeed being adequately undertaken in a technology transfer alliance will also depend on the scope or complexity of the payoff relevant actions. For example, increases in the number of products or technologies included in a contract, or increases in the geographic scope of the transaction, will inevitably increase the difficulty and cost of monitoring activities (as well as possibly exacerbating specification problems). Similarly, if a contract is used to govern a project involving multiple firms, monitoring costs will increase with the number of partners involved, as assigning accountability for pay-off relevant actions taken by multiple partners under uncertainty is problematic (Alchian and Demsetz, 1972). This suggests that the scope of transactions should be limited unless there are compelling reasons to do otherwise, for example, because of the need to bring together diverse elements in a single project. Where increased scope is necessary, a more hierarchical governance structure is indicated. Thus we have

Observation 2. A more hierarchical governance mode will be chosen for transactions involving a broader range of products or technologies.

Observation 3. A more hierarchical governance mode will be chosen for transactions covering a wider geographic area.

Observation 4. A more hierarchical governance mode will be chosen when there are more firms involved in a transaction.

Enforcing technology transfer contracts when a violation of contract terms is detected can be problematic: Particularly in the international arena, differential enforcement of technology contracts can play a large role in governance choices in interfirm alliances as patent laws and their enforcement vary considerably across countries (despite recent efforts at harmonization through the GATT). Where alliance partner firms are all based in a single country (as in the empirical analysis below) there may be differences in the efficacy of patent protection across industries, but these are rooted primarily in the nature of the associated technologies and the subsequent ease or difficulty with which property rights can be specified. Therefore, while we would expect there to be significant cross-national differences in the governance of similar transactions within interfirm alliances, based on enforcement differences, we have no similar expectations regarding interindustry differences in enforcement in the United States.[9]

The relationship between transaction characteristics and the governance structure adopted for an alliance may also be influenced by the presence of alternative safeguards that can act as partial substitutes for more formal governance instruments. One such alternative safeguard is the exchange of hostages involved when firms are linked in multiple ongoing alliances. If the parties to an alliance are involved in other alliances together (whether contractual or equity based), then the payoffs to opportunism within each alliance are lowered, because of the risk that continued gains from cooperation in all of the alliances will be withdrawn (Gulati, 1995; Kogut, 1989). Alternatively, repeat alliances may reduce adverse selection problems in partner choice because of improved information developed over the course of previous cooperative projects (whether ongoing or not), regarding a partner's technological capabilities, assets, and behavior (Balakrishnan & Koza, 1993). Thus, we have:

Observation 5. Less hierarchical governance modes will be chosen if the partners are involved in multiple alliances together.

4. Empirical Analysis

4.1 Data Source

The principal data source for the empirical study is the Cooperative Agreements and Technology Indicators (CATI) information system, a relational database covering over 9000 cooperative agreements involving some 3500 different parent companies in many different industries and countries (Hagedoorn & Schakenraad, 1990). Cooperative agreements in the CATI database are defined as "common interests between independent industrial partners which are not connected through majority ownership," and all involve some arrangement for technology transfer or joint research.

The CATI data is based on systematic examination of secondary reports of alliance formation, primarily during the 1980s. In addition to the organizational form of the alliance, the database includes information on the identity and nationality of the partners, the date of establishment, the type and scope of the transaction involved, and the industry or technology sector in which the cooperative agreement takes place. Coverage of the overall population of global alliances is inevitably incomplete, and there are significant biases in the data, particularly with respect to the geographic and industrial sectors covered.[10] Such biases and omissions arguably render the data unsuitable for analysis of overall alliance activity or of firms' propensity to form strategic alliances. How-

9. A set of industry dummy variables is included in the empirical model, to control for any sectoral differences in patent protection or in the use of different types of alliances that are related to other omitted variables.

10. Hagedoorn and Duysters (1993:1) describe the shortcomings of the data as follows: "... skewness in the distribution of modes of cooperation (i.e., an underestimation of the number of customer-supplier relations and licensing agreements, due to under-reporting in published media), ... some geographic—i.e., Anglo Saxon—bias ... an underestimation of certain technological fields not belonging to modern core technologies and ... some overrepresentation of large firms."

ever, conversations with the originators of the data and independent verification of data on a random sample of alliances confirm that there are no systematic biases in the description and coding of alliance form and activities. Thus the reported biases are not critical here, as we are looking at individual decisions regarding the choice of organizational form.

4.2 Sample and Dependent Variable

The primary sample comprises all horizontal technology transfer alliances between public U.S.-based manufacturing firms in the CATI database established during the period 1980–1989: a total of 165 alliances. Restricting the analysis to public firms undoubtedly introduces some bias into the sample, as many of the smallest firms will be excluded. This is unavoidable, however, since the firm-specific data necessary for analysis of the "complete" model, including control variables (see below), are not readily available for private companies. To assess whether the restricted sample materially affects the results, a simplified model was also estimated for a larger sample of alliances which included private and nonmanufacturing firms. This latter sample comprises 507 alliances, and the model includes only those variables derived from CATI data.

For our sample of horizontal technology transfer alliances, the dependent variable (FORM) takes on one of three values, as discussed earlier:

> FORM = 0 for unilateral contractual agreements (i.e., for second-sourcing and licensing agreements)
> FORM = 1 for bilateral contractual agreements (i.e., for mutual second-sourcing agreements, cross-licensing, and technology sharing agreements)
> FORM = 2 for equity-based alliances (i.e., joint ventures)

The alliances in each of the two samples are fairly evenly distributed among these alliance types: for the "public" sample of 165 alliances and the expanded sample of 507 public and private firm alliances, respectively, 69 (42%) and 244 (48%) are unilateral contractual agreements, 60 (36%) and 135 (27%) are bilateral contracts, and 36 (22%) and 128 (25%) are equity-based alliances.

4.3 Independent Variables

A list of independent variables is shown in Table 1, with the relevant sources, and hypothesized signs. All firm-specific information is derived from Compustat data[11] and Table 2 presents the means, standard deviations, and range of values for the independent variables in the sample of 165 alliances between public U.S.-based firms. None of these variables are highly correlated: the largest correlation coefficient is 0.601, between venture experience and average size of alliance partners.

11. Because Compustat data is based on firm-level observations and many of the firms in the CATI database are actually subsidiaries of larger companies, the first step in obtaining this information was to match subsidiaries with their parent companies in the year the alliance was established. This was accomplished using the *Directory of Corporate Affiliations* for the relevant years.

Table 1. Independent Variable Definitions and Sources

Variable	Definition	Source	Predicted Sign
Transaction type	Activities covered by agreement: product and process design, production and marketing or "mixed."	CATI	+
Technology scope	Range of products or technologies covered by the agreement.	CATI	+
Geographic scope	Geographic scope of alliance: U.S. or North America, or worldwide.	CATI	+
Number of partners	Number of firms in alliance.	CATI	+
Overlapping agreements	Number of previously established alliances linking partner firms.	CATI	–
Control Variables:			
Industry	CATI technology sectors—biotechnology, information technology, new materials and "other."	CATI	n/a
Average firm size	Average size of alliance partners (total assets in millions of 1982 dollars).	Compustat	n/a
Relative size	Ratio of smallest firm to largest firm, measured by total assets.	Compustat	n/a
Average R&D	Combined R&D intensity of alliance partners (total R&D spending/total sales).	Compustat	n/a
R&D gap	Maximum difference among partners' R&D spending/sales.	Compustat	n/a
Same industry	Coded 1 if "main four-digit SIC" is same for all alliance partners.	Compustat	n/a
Alliance experience	Average number of previously established alliances for partner firms.	CATI	n/a

The number of partners was excluded as an independent variable for analysis of the "public firm" sample of 165 alliances, as there were only two alliances in this sample having more than two partners.[12] The number of partners is reintroduced in the model for the full sample of 507 firms, however. The overlapping alliances variable (a measure of alternative safeguards) is the number of alliances in the CATI database established prior to the establishment date of the alliance in question and involving all of the same partner firms.

In addition to the independent variables featured in the hypotheses, the following control variables were included in the model:

- Technology/research field or industry: A series of dummy variables were included, based on the "core technology sectors" identified in the CATI database: "information technology," "new materials," and "biotechnology." Observations without a dummy variable attached are

12. This reflects the large proportion of multipartner alliances with at least one private or nonmanufacturing firm for which the required Compustat data was unavailable.

Table 2. Descriptive Statistics for Independent Variables

	Mean	Standard Deviation	Minimum	Maximum
Design transaction dummy 1 = design 0 = production or mixed	0.078	0.269	0	1
Mixed transaction dummy 1 = mixed 0 = production or design	0.120	0.326	0	1
Technology scope 1 = few or broad range of technologies or products 0 = single technology or product area	0.365	0.483	0	1
Geographic scope 1 = Global Operations 0 = USA or N. America	0.267	0.444	0	1
Overlapping agreements = number of alliances linking partner firms	2.018	1.684	1	9
Information technology dummy	0.491	0.501	0	1
Biotechnology dummy	0.150	0.358	0	1
New materials dummy	0.126	0.333	0	1
Average size = average size of partners (total assets, in $millions)	11.20	14.55	0.036	77.18
Asset ratio = total assets of smallest partner/total assets of largest partner	0.234	0.256	0.001	0.997
Combined R&D intensity = total R&D spending/total sales	0.062	0.041	0.003	0.259
R&D gap = largest difference among partners' R&D spending/sales	0.136	0.371	0.001	2.524
Same industry 1 = all partners have same "main 4-digit SIC" 0 = otherwise	0.120	0.326	0	1
Alliance experience = average total number of alliances of partner firms prior to this alliance date	16.50	13.49	0	65
Time trend 0 = 1980	5.46	2.57	0	9

all other technology sectors represented in the CATI data.[13] This variable controls for significant sectoral differences in the propensity to enter into certain types of alliances that are not captured in the transaction or firm-level independent variables.

- Firm size: Previous studies of the decision to enter joint ventures, and of joint venture performance, have included among the independent variables the absolute size of the firm (e.g., Agarwal & Ramaswami, 1992; Gomes-Casseres, 1990) and/or the asymmetry in the size of participating firms (Harrigan, 1988; Hennart, 1991a). Average size (measured as total assets in 1982 dollars) of the partner firms in the alliance, and the "size ratio" of the firms (i.e., the total assets of the smallest firm in the alliance divided by the total assets of the largest firm) are therefore included in the model.[14]
- R&D intensity: The combined R&D intensity (i.e., total R&D spending/total revenues) of the partner firms is included as a control, since R&D intensity has been a significant (though not consistent) explanatory variable in previous studies of joint venturing versus autonomous international investment (Agarwal & Ramaswami, 1992; Gomes-Casseres, 1989; Hennart, 1991a; Kogut & Chang, 1991).[15]
- R&D gap: A relevant finding from the technology transfer literature is that a large "capabilities gap" between the technology donor and recipient increases the costs of transferring technology across firm boundaries (Teece, 1981). R&D gap, measured as the absolute value of the largest difference in the R&D intensities of partner firms, is therefore included as a proxy to control for the potential impact of such a "capabilities gap."
- Partners in same industry: Also following previous studies (e.g., Balakrishnan and Koza, 1993; Gomes-Casseres, 1989; Hennart, 1991a), a control dummy is included that captures whether both (or all) alliance partners have their primary operations in the same industry (at the four-digit SIC code level).
- Alliance experience: If experience in alliances lowers governance costs

13. The distribution of alliances among the core and other sectors in the CATI database is as follows: information technology, 40%; biotechnology, 15%; new materials, 10%; "other," 35%. "Other" sectors (ordered by share of alliances in the database) are automobiles, engineering, electrical equipment, defense, consumer electronics, instruments, aircraft, food and beverage, mining, medical technology, and space technology.

14. All of the firm-specific information is for the year of establishment of the alliance in question. Firm assets are deflated to 1982 levels based on the capital goods producer price index (U.S. Department of Commerce, 1992).

15. R&D intensity based on the level of sales is an imperfect indicator of R&D efforts as the measure may fluctuate quite widely as sales levels vary. Alternative measures include R&D spending level or R&D intensity based on total assets (which are less variable over time). Using R&D levels introduces additional problems however, as they are strongly correlated with total assets. The analysis was nonetheless repeated with both of these alternative specifications, with no significant impact on the results. Therefore only results using R&D intensity based on total revenues are reported.

more for certain modes than for others, then total alliance experience may affect the choice of mode. A control variable was constructed based on the average number of alliances (in the CATI database) established by each partner firm prior to the establishment date of the alliance in question. Although this measure is inevitably biased over time, this likely reflects the actual experience of firms in the sample, since technology-related alliances were not a common feature of firm strategy prior to the 1980s (Contractor and Lorange, 1988; Hagedoorn and Schakenraad, 1993).

- Time trend: To capture any systematic change in alliance structures adopted over time, an annual time trend variable is included, which takes a value of 0 for alliances established in 1980 to 9 for alliances established in 1989.

4.4 Statistical Methodology

As discussed above, the unit of observation for the analysis is the alliance. Because the categorical dependent variable can take on one of three ordered values, ordered probit is used for the statistical analysis.[16] The model is specified as follows:

$$z_i = \beta X_i + \varepsilon_i, \tag{1}$$

where z_i is an unobservable measure of the position of alliance i in the market-hierarchy continuum, X_i is the vector of characteristics of the transaction and of the participating firms (shown in Table 1), β is the weight attached to each characteristic, and ε_i is a random error term.

Since we only observe the choice of one of three ordered governance modes for each alliance ("FORM_i"), we assume that the unobservable variable z_i can be broken up into discrete intervals that "map" into the categories for FORM_i.

$$\begin{array}{ll} \text{If } z_i < \mu_0 & \text{then FORM}_i = 0 \\ \text{If } \mu_0 \le z_i < \mu_1 & \text{then FORM}_i = 1 \\ \text{If } \mu_1 \le z_i & \text{then FORM}_i = 2 \end{array} \tag{2}$$

The underlying model consists of the variables (z_i, X_i) given in Equation (1). The observed variables are X_i and FORM_i, where the observation scheme is given by Equation (2). The objective of the statistical analysis is to estimate β in Equation (1), the parameters which describe the relationship between characteristics of the alliance and participating firms with the position on the market-hierarchy continuum, and how this gets translated into one of the ordered

16. The probit model assumes that the underlying probability distribution is normal. In the common alternative to this model, the logit, the probability distribution is assumed to be logistic. The difference between these cumulative distributions is small (except in the tails), so the results should not be sensitive to the choice between these models, unless there are a large number of observations in the tails (Maddala, 1983). To ensure that this condition was not operable in the samples analyzed here, the models were estimated using both ordered probit and ordered logit. No significant differences in the results were observed, and so only the ordered probit results are reported.

categories of organizational form (FORM_i). We can write the probabilities of falling into the various categories of the dependent variable as

$$\begin{aligned}
\Pr(\text{FORM}_i = 0|X_i) &= \Pr[\varepsilon_i < (\mu_0 - \beta X_i)|X_i] = F(\mu_0 - \beta X_i) \\
\Pr(\text{FORM}_i = 1|X_i) &= \Pr[(\mu_0 - \beta X_i) \leq \varepsilon_i < (\mu_1 - \beta X_i)|X_i] \\
&= F(\mu_1 - \beta X_i) - F(\mu_0 - \beta X_i) \\
\Pr(\text{FORM}_i = 2|X_i) &= \Pr[\varepsilon_i \geq (\mu_1 - \beta X_i)|X_i] = 1 - F(\mu_1 - \beta X_i)
\end{aligned} \tag{3}$$

where $F(.)$ denotes the cumulative normal distribution function corresponding to the distribution of the random variable ε_i—for the ordered probit model, this is a normal distribution, with the normalization that the variance of $\varepsilon_i = 1$.

Some normalization is also necessary on the (unknown) cutoff points, μ_j. Following common practice, we assume that $\mu_0 = 0$. Then, for the ordered probit model,

$$\begin{aligned}
\Pr(\text{FORM}_i = 0|X_i) &= \phi(-\beta X_i) \\
\Pr(\text{FORM}_i = 1|X_i) &= \phi(\mu_1 - \beta X_i) - \phi(-\beta X_i) \\
\Pr(\text{FORM}_i = 2|X_i) &= 1 - \phi(\mu_1 - \beta X_i)
\end{aligned} \tag{4}$$

where ϕ is the cumulative distribution for a standardized normal variable.

5. Results and Discussion

Estimation results, shown in Table 3, provide support for most of the transaction cost hypotheses. In model 1, based on the sample of 165 "public company alliances," more hierarchical types of alliance were chosen for design and mixed activity transactions than for alliances governing only production or marketing activities. Thus, as hypothesized, firms choose more hierarchical arrangements in situations where specification of the relevant property rights can be expected to be problematic. Furthermore, the positive coefficient on "mixed" (2.947) transactions is significantly higher than for design alone (1.225). This parallels Pisano's findings, that R&D collaborations in the biotechnology industry involving both R&D and other functions were more likely to use equity links than were "pure" R&D agreements (Pisano, 1989).

More hierarchical forms were also chosen when multiple products or technologies were involved in the alliance. The hypothesis links this effect to elevated monitoring difficulties (and hence appropriability hazards) associated with broader transaction scope. However, we have only a dummy variable capturing this aspect of transaction scope, with "Technology Scope" equal to zero for alliances covering a single technology or product area and equal to one for multitechnology/product transactions. This variable is therefore potentially open to alternative explanations: for example, while a unilateral contract may involve activities related to multiple products or technologies and bilateral contracts may involve technology exchanges within a single technology area,[17]

17. This contention is borne out in the data where there are a nontrivial number of cases of multitechnology unilateral contracts and single-technology bilateral contracts.

Table 3. Ordered Probit Estimation Results

	1	2	3	4
Intercept	−0.127	−0.165	0.574*	−0.611*
	(.373)	(.319)	(.326)	(.349)
Design transaction	1.225***	1.185***		1.392***
	(.291)	(.280)		(.192)
Mixed transaction	2.947***	2.966***		2.359***
	(.458)	(.445)		(.160)
Technology scope	1.225***	1.239***		1.113***
	(.286)	(.257)		(.133)
Geographic scope	−0.630	−0.679*		−0.481**
	(.405)	(.391)		(.189)
Overlapping agreements	−0.060	−0.017		0.025
	(.085)	(.080)		(.064)
Number of partners	n/a	n/a	n/a	0.196**
				(.099)
Biotechnology dummy	−0.180	−0.231	0.113	−0.264
	(.503)	(.389)	(.330)	(.197)
Information technology dummy	−0.244	−0.375	−0.211	−0.088
	(.330)	(.295)	(.252)	(.144)
New materials dummy	−0.637	−0.670**	−0.479	−0.344**
	(.325)	(.295)	(.287)	(.174)
Time trend	0.057	0.042	0.011	0.024
	(.055)	(.046)	(.043)	(.064)
Average size (assets)	0.006		0.010	
	(.016)		(.013)	
Asset ratio	−0.194		0.069	
	(.571)		(.394)	
Combined R&D intensity	−1.968		−2.327	
	(4.20)		(3.69)	
R&D gap	0.051		−1.166	
	(.458)		(1.70)	
Same SIC	−0.061		−0.212	
	(.469)		(.324)	
Alliance experience	−0.004		−0.005	
	(.007)		(.006)	
Log of likelihood function	−121.3	−122.3	−172.4	−368.6
χ^2	108.75***	106.67***	10.28	329.26***
Percentage of outcomes predicted correctly	73%	73%	37%	73%
Sample size (n)	165	165	165	507

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$
Standard errors in parentheses

a bilateral agreement may not be a feasible alternative in some instances, if there is only one party with a technological asset to offer.[18] To ensure that

18. I thank one of the anonymous reviewers for this insight.

Table 4. Frequencies of Actual and Predicted Outcomes

	Predicted			
Actual	0	1	2	Total
0	60	6	3	69
1	20	39	1	60
2	5	9	22	36
Total	86	53	26	165

the result on technology scope is not driven solely by such cases, all unilateral arrangements were removed and a binomial model of governance choice was estimated (for the choice between bilateral contracts and equity joint ventures), with similar results in terms of directional effects and levels of significance for all variables.

Overall, model 1 correctly predicts the organizational form of 121 out of the 165 alliances (73.3%). This compares with a random assignment, which would be correct for only 33% of the alliances, or 42% correct if all observations were assigned to the most frequently observed structure, that is, unilateral contract. Furthermore, as shown in Table 4, the "hit rate" is significantly higher than would be expected with random predictions in each of the three organizational form categories.[19]

Although it had the expected negative sign, the coefficient on the overlapping agreements variable was not statistically different from zero, in contrast to the findings in Gulati (1995), discussed earlier. A possible explanation for this inconsistency is that the variable used in the present study is an imprecise proxy for ongoing links between the firms: some agreements between the relevant firms may not be included in the CATI data and there is no data available on alliance dissolution or total project value, which are relevant to a hostage exchange model of overlapping alliances. Taken together these limitations suggest that the coefficient on overlapping alliances should be interpreted with caution.[20]

The estimated coefficient on geographic scope is negative, contrary to the hypothesized sign, and is almost significant at the 10% level. Thus, alliances covering worldwide operations, if anything, tend to be less hierarchical than those covering only North American operations. This finding should again be interpreted cautiously, however, as we do not have complete information about the age and value of the technology in each alliance and it is possible that there are systematic but unobserved differences in the characteristics of technology governed in alliances of differing geographic scope. If firms decline to transfer their newest or most valuable technology in situations where monitoring is particularly problematic—for example, when geographic scope is great—then

19. The ordering of the three categories was also confirmed by estimation of a multinomial logit model which generated results consistent with the findings reported here.

20. Note, however, that Gulati's data also suffers from shortcomings related to a lack of data on alliance dissolution and project value data.

the observed distribution of alliances in these settings may be skewed toward licensing, which is well suited for transfer of older, simpler, more codified technology.[21] More generally, there is a problem of simultaneity in the investment decision: a firm will jointly determine the content and governance of the transaction, that is, what technology will be shared or transferred, and how that transfer will be organized. Although the present study goes further than previous studies in specifying transaction-level variables, we are still unable to completely control for these effects.

An interesting aspect of the estimation results is that none of the control variables is significant—in contrast to previous studies of the choice between internal organization and joint ventures. Here, we see no significant effect on the form of strategic alliances, of firm size (either the average or relative size of the partners), R&D intensity, alliance experience, or the industry in which the alliance operates. This result is also supported in models 2 and 3, which show that a model including only the hypothesized variables performs essentially as well as the full model in accurately predicting the alliance form (72.7% of alliances are correctly predicted), while a model including the control variables alone can predict only 37% correctly.

These results emphasize an important finding of the current study: that it is attributes of the transaction and not firm-level characteristics that determine the type of alliance form chosen. This may also explain the inconsistencies of results in the international business literature that are based on firm-level measures, for example with respect to the effect of R&D intensity on governance mode (Gomes-Casseres, 1989).

Estimation of model 4, on the expanded sample of horizontal technology transfer alliances (still involving U.S.-based firms only), produced very similar results to those in model 2, with essentially the same variables. All the coefficients have the same sign as before, with similar levels of significance.[22] However, since this larger sample includes sufficient alliances with more than two partners to allow inclusion of "number of partners" as an independent vari-

21. Previous studies of franchising arrangements suggest an alternative explanation of the negative coefficient on geographic scope. In several studies (Brickley and Dark, 1987; Lafontaine, 1992; Minkler, 1990), measures of geographic dispersion, such as distance from monitoring headquarters or number of states in which the chain has established outlets, are used as proxies for difficulties in direct monitoring of agents' effort. These variables are found to be negatively related to the probability that an outlet will be company owned. The inference is that monitoring difficulties increase the need for high-powered incentives, and thus increase the attractiveness of contractual (versus integrated) solutions. However, in the current study focusing on appropriability hazards in alliances, high-powered incentives have perverse effects, as they increase the probability that technology will be put to uncompensated use outside the scope of the agreement. More hierarchical governance modes are thus the expected response to increased difficulties in monitoring.

22. The robustness of the estimation results suggests that the bias in the "public firm sample" does not have a material effect. This is consistent with the logic of the model, since the theory operates at the level of the transaction rather than at the firm level. Therefore, absent systematic differences in transactions tied to characteristics of the firm, sample biases in firm characteristics should be inconsequential.

able, there is an additional result of interest here: the effect of the number of partners on alliance structure is as hypothesized, suggesting that the increase in anticipated monitoring problems associated with multiple alliance partners induces the partners to choose a more hierarchical alliance structure.

6. Conclusions and Suggestions for Future Research

The empirical results reported above provide strong support for the hypothesis that appropriability hazards are an important consideration when firms establish strategic alliances. When appropriability hazards are severe, because of difficulties in specifying contracts for technology or in monitoring contracting partners' activities, more hierarchical alliance types are chosen. These alliances feature bilateral dependency (hostage exchange) or equity ties which promote monitoring and incentive alignment. Moreover, in contrast to most related studies in the international business arena, the analysis suggests that the form of an alliance depends primarily on the attributes of the transaction itself, rather than on characteristics of the partner firms.

The major limitation of the empirical analysis is the paucity of detailed data on specific technologies transferred in the sample alliances. This means that it is not possible to completely control for simultaneity in the investment decisions. Overcoming this problem would require information on the type of technology in an alliance, in terms of its value and level of advancement relative to the state of the art (which together determine the upper bound on the losses associated with appropriability hazards in a contracting relationship), as well as measures of the tacitness of know-how involved in technology transfers. While this study goes further than most previous work on interfirm alliances in specifying transaction-level variables, development of a more microanalytic data set is clearly a useful undertaking for future work.

The theoretical framework and empirical analysis described in this article nonetheless have important implications for future research. The theory provides a systematic way to differentiate among the many different types of interfirm alliance, and suggests that there is a clear logic to the choice among these different alliance types. Furthermore, the focus on interfirm alliances involving technology transfer provided an ideal setting for exploration of the origins and governance implications of appropriability hazards, or hazards related to weak property rights, that previously have been underdeveloped in transaction cost economics.

There are several avenues for further development of the research, in addition to the one mentioned above. One extension involves testing the hypotheses developed here on a larger sample of alliances involving firms from different countries. This would allow us to examine whether the same logic informs cross-national interfirm organization as it applies to alliances involving only U.S.-based firms. Enforcement issues could also be highlighted in this analysis by examining the added effect of cross-national differences in protection of intellectual property rights (as well as other aspects of the institutional environment) on the choice of organizational form in alliances between firms of different nationalities.

More ambitious extensions to the research would include an examination of the interaction between asset specificity and appropriability hazards over the life of an alliance. The data requirements and complexities of such an undertaking are challenging, as a series of longitudinal studies would be required to facilitate assessment of the evolving relationship between the different contracting concerns. Such a series of studies could address a rich set of questions, however, perhaps including the following: Does the nature of the technology transferred and the scope of projects vary over the course of an alliance? How are governance mechanisms adapted? How do relationship-specific assets develop over the course of an alliance? What is the role (if any) of transaction-specific investments in the equilibration of hazards in the face of appropriability concerns? Can such investments actually reduce contracting hazards in these circumstances?

The prospects for further theoretical and empirical study here are rich and exciting. The challenge is to approach these opportunities in a rigorous and incremental manner, maintaining the strictly comparative institutional approach which is a key advantage of the transaction cost framework.

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