MANAGERIAL AND DECISION ECONOMICS
Manage. Decis. Econ. **25:** 421–436 (2004)
Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/mde.1199

Organizational Choice in R&D Alliances: Knowledge-Based and Transaction Cost Perspectives

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This study examines how firms choose organizational form for their R&D alliances. Encouraging cooperation in these alliances is often challenging, given the difficulties in knowledge sharing between partners and protecting the property rights over partner knowledge. Interestingly, knowledge-based and transaction cost perspectives generate different hypotheses on alliance organization choice in this setting. When partner knowledge bases are very different, the risk of unintended transfer or leakage is reduced, yet the need for enhanced communication and knowledge sharing mechanisms remains undiminished. With a sample of 232 R&D alliances, I find more thorough support for the transaction cost hypothesis. Firms more likely select an equity joint venture as partner knowledge bases diverge and knowledge transfer becomes more difficult. When such knowledge bases are very different, however, firms are less likely to choose an equity joint venture over more contractual forms of alliance organization. Thus, these results provide empirical evidence on alliance organization choice and also have important implications for the fundamental question of why firms exist. **Copyright © 2004 John Wiley & Sons, Ltd.**

INTRODUCTION

In recent years, inter-firm R&D alliances have become more common (Hladik, 1985; Morris and Hergert, 1987; Mowery, 1988). Such alliances allow firms to access new technologies, realize economies of scale and scope in their R&D activities, and shorten development time.[1] These benefits may extend beyond the life of the alliance, as firms learn skills and gain competencies from their partners (e.g. Mowery *et al*., 1996, 1998). Yet, to benefit from R&D collaboration, firms must create a structure that both supports the efficient transfer of knowledge based assets and also minimizes unintended leakage of such assets to potential competitors. Here, I examine how firms choose alliance organization for collaborative R&D. Further, because of the need to both transfer knowledge and control against unintended leakage in R&D alliances, this setting provides a unique opportunity to examine the tension between knowledge-based and transaction cost perspectives.

Theory suggests that alliance organizational form choice, or governance, influences both the ease of knowledge flow and incentives to share knowledge. Knowledge-based theories, such as those put forth by Kogut and Zander (1992), emphasize the use of firm or internal organization as a means to increase productive knowledge flow. Following this argument, difficulties in knowledge transfer between firms—such as when knowledge is tacit or firms lack absorptive capacity—imply greater benefits from internal organization. In contrast, transaction cost economics (TCE) emphasizes the use of internal organization to

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preserve incentives to cooperate and share knowledge via controlling threats of opportunism.

Each theory has different insights into how organization is chosen; however, an empirical comparison of the knowledge or resource-based theory and transaction cost economics has been lacking in the literature to date. Such a comparison is often not possible, since these two theories generate similar predictions regarding organization choice in most cases.[2] However, to establish that knowledge- and opportunism-based theories have distinctive predictive content, we must show situations where each theory generates a different prediction (Conner and Prahalad, 1996; 489). If we can identify such a situation, we may be able to gain deeper insights into the fundamental question of why firms exist. Here, in the case of R&D alliances, we have such a situation. When we consider the diversity of technologies brought by each partner to the alliance, issues of both knowledge transfer and opportunism are raised and the two theories predict different organizational form choices for R&D alliances.

While a multitude of possible organizational forms fall within the broad rubric of 'alliances', I focus on two categories of alliance organization in my analysis below: the bilateral contract and the equity joint venture. Relative to the bilateral contract, the equity joint venture more closely resembles internal organization. Applying knowledge-based and transaction cost theories, the equity joint venture facilitates knowledge flow and safeguards against leakage better than the bilateral contract. However, the equity joint venture is more costly to set up and administer. Thus, firms likely choose equity joint ventures when the benefits from enhanced knowledge transfer and control are greater than these additional set up and administration costs. To determine the need for transfer and control in a particular R&D alliance, I consider diversity of partner technological portfolios.

When allying firms have very similar knowledge bases or technology portfolios (i.e. many capabilities in common), there is less knowledge to transfer and control. As such, the need for the enhanced knowledge transfer and control characteristics of the equity joint venture is reduced. In this sense, knowledge-based and transaction cost arguments converge to produce similar predictions on the relationship between technological diversity and organization choice. However, when partner knowledge bases are very different, these predictions diverge. I argue that a lack of absorptive capacity reduces the threat of knowledge leakage and, thus, the need for the equity joint venture under transaction cost arguments. In contrast, the need for organizational form facilitating better knowledge flows and communication among partners, however, is undiminished. In this sense, the two theories predict different choices of alliance organization when partner knowledge bases are very different.

Using a sample of 232 R&D alliances in the telecommunications equipment industry, I test predictions from the two theories. Allying firms more likely choose an equity joint venture over the bilateral contract as partner knowledge bases diverge and knowledge transfer becomes more difficult. However, when partner knowledge bases are very different, such that partners have little or no knowledge in common, firms are less likely to choose an equity joint venture over more contractual forms of alliance organization. Thus, it appears that TCE arguments better explain organization choice, at least in the context of R&D alliances.

In the paragraphs that follow, I first discuss the bilateral contract and equity joint venture in terms of their information flow and control characteristics. I explore differences in partner knowledge portfolios and the implications of such differences for organization choice; hypotheses are developed on this basis. Descriptions of the sample used, measures and statistical methods follow. Results and discussion conclude.

ALLIANCE ORGANIZATION ALTERNATIVES: TWO THEORETICAL PERSPECTIVES

Alliance organizational forms range from simple licensing arrangements to more complex forms such as the equity joint venture where firms incorporate a separate entity for their collaborative efforts.[3] I focus here on two such alternatives: the bilateral contract and equity joint venture. A bilateral contract is a contractual arrangement where partner firms pool their capabilities for the purposes of collaborative R&D, but do not form a separate legal entity. In an equity joint venture, firms similarly pool their capabilities, but also

create a new entity that is jointly owned and operated by two or more allying firms (Pisano *et al*., 1988; Oxley, 1997).[4] The characteristics of each organizational form ultimately determine how firms choose between these two forms for their alliance activities.

Conceptually, the bilateral contract and equity joint venture lie on the organizational continuum between market and hierarchy and, as 'hybrids', embody governance characteristics that lie somewhere between these two extremes (Kogut, 1988; Williamson, 1991; Oxley, 1997). Relative to the bilateral contract, the equity joint venture more closely resembles hierarchy and has some unique attributes that influence a firm's ability and incentives to share knowledge-based capabilities. All equity joint ventures have a joint board of directors, which is composed of members from all partner firms (Killing, 1983). Via this joint board of directors, firms can better communicate as well as veto strategic decisions regarding alliance activities (Killing, 1983).[5] Each partner firm also has limited powers of fiat over employees of the alliance in an equity joint venture. Even where joint venture personnel are drawn from the parent firms, these personnel often become employees of the venture rather than of the parent firms.[6] As all firms involved have a managerial presence in the venture via the joint board, each partner has some control over the promotion or demotion of workers that are over- or underperforming as well as some influence over the allocation of workers to specific tasks.[7] As Killing (1983: 26–27) notes,

> '*Communication between the venture and the parent company is likely to be improved, simply because employees of the two firms know each other. More complete information offers the prospect of more complete control. Secondly, such an employee is likely to act in ways which this parent would find acceptable, even when his actions are not overtly controlled.*'

Equity joint ventures also provide internal means of dispute resolution between partners. These internal disputes resolution mechanisms often require, for example, that senior management negotiate the dispute prior to third party resolution. In organizational forms closer to the market, such as the bilateral contract, such mechanisms are less common.[8] More importantly, firms have a greater incentive to work out disputes privately under the equity joint venture. Because the equity joint venture relieves partners from complete specification of rights and obligations of partner firms, courts have less advanced guidance on partner intent, making court resolution less efficient. Finally, as the alliance organizational form most closely resembling internal or firm organization, equity joint ventures are often characterized as having a common stock of knowledge and organizing principles that facilitate information flow and communication within the boundaries of the alliance (Kogut and Zander, 1992).

These characteristics of the equity joint venture have implications for how well firms can share knowledge with their partners and, at the same time, safeguard against leakage. The knowledge-based and transaction cost perspectives usefully highlight these implications. While these theoretical perspectives focus on the characteristics of firms relative to markets (or spot contracts), we can make inferences about what each perspective implies about alliance organization, given that the equity joint venture resembles a firm more closely than a bilateral contract does.

Proponents of the knowledge-based perspective view argue that firms have distinct advantages over markets that are unrelated to controlling the threat of opportunism (Conner, 1991; Kogut and Zander, 1992; Conner and Prahalad, 1996). Thus, internal organization may be an efficient choice of organization even when there is no threat of opportunism. For example, firms have particular characteristics that make knowledge sharing easier within the firm than between firms. Arrow (1974) states that communication within the firm is more efficient because firms, unlike markets, have a 'common code'. On the basis of this insight, Kogut and Zander (1992) argue that more hierarchical organization is a superior means to transfer knowledge or other tacit information. Firms have 'a set of higher-order organizing principles [that] act as mechanisms by which to codify technologies into a language accessible to a wider circle of individuals' (Kogut and Zander, 1992: 389). Because of this common stock of knowledge and organizing principles, sharing knowledge, particularly tacit or complex knowledge is easier within the firm than between firms. Thus, internal organization arises when knowledge to be shared is tacit or complex, because the costs of

communicating and coordinating in a market relationship are relatively higher.[9]

Beyond enhanced knowledge sharing and communication, a firm also permits knowledge substitution and greater flexibility. The knowledge substitution effect, 'concerns how presently held knowledge is applied to the activity' (Conner and Prahalad, 1996: 484). This means that, within the firm, an individual may use the knowledge of another before that individual fully understands the knowledge. In contrast, 'a main effect of market contracting—of an autonomous relationship—is to oblige knowledge to be internalized before the individual agrees to modify its actions on the basis of that knowledge' (Conner and Prahalad, 1996: 485). Thus, the manager's knowledge partly substitutes for the employee's knowledge (Foss, 1996: 520). Internal organization arises, therefore, when knowledge absorption or sharing is perceived to be difficult, because the knowledge substitution effect eliminates the need to fully communicate difficult or complex knowledge.

Flexibility refers to the ease of changing each party's rights and obligations over the course of the relationship, 'in order to incorporate learning or unexpected opportunities arising during the course of the work' (Conner and Prahalad, 1996: 486). Firms provide greater flexibility, since internal arrangements do not require renegotiation when unanticipated contingencies occur, while market contracts typically do. Thus, internal organization arises when the difference in perspectives between two parties is pronounced, such that renegotiation would be costly. For example, internal organization is ideal when two parties have very different knowledge sets, which makes transferring or sharing ideas between them costly (Conner and Prahalad, 1996: 486). Kogut (1988) applies similar arguments in the context of alliances and argues that equity joint ventures are ideal when transfer of complex knowledge is desirable, because the equity joint venture more closely replicates the firm than more contractual alliance forms.[10] Thus, applying these arguments to alliance organization choice, the equity joint venture is preferred when: (1) tacit or complex knowledge must be shared or transferred between partners; (2) the use of knowledge complementary to this tacit knowledge must be used in a way that is only foreseen by the partner with the tacit knowledge; and/or (3) partner knowledge sets are very different, such that partners have difficulty incorporating unexpected learning opportunities if alliance renegotiation is required.

Proponents of the transaction cost perspective also state that the firm has key advantages over market organization, but argues that these advantages primarily relate to the control or reduction of opportunism threats posed by the transaction characteristics (Williamson, 1985; Oxley, 1997). In the absence of threatened opportunism, all transactions could be organized by a series of contracts, such that the firm would be an unnecessary organizational form—according to this view. By the imposition of bureaucracy, partner incentives to behave opportunistically are diminished because there is greater monitoring and control over partner actions and greater incentives to work out disputes privately (rather than by recourse to the courts). As a result, incentives to cooperate and share knowledge are preserved.

The joint board of directors in the equity joint venture allows communication of pertinent information to and coordination of the collaborative activities by parent firms (Pisano *et al*., 1988; Oxley, 1997). Control is also enhanced as partner firms bear the right of veto over strategic level decisions regarding joint venture operations (Killing, 1983). In this sense, the joint board facilitates greater monitoring of alliance activities. This joint board of directors also allows greater control over day-to-day operations, because partners may veto upper management level decisions and have some power of fiat over the employees of the venture. The opportunity for leakage is, therefore, reduced and penalties exist if leakage does occur. Equity joint ventures also provide firms with explicit means to respond to unanticipated contingencies (or opportunities) that arise over the course of the alliance. By providing means for partners to adapt in a coordinated fashion, the equity joint venture relieves partners from fully specifying contractual arrangements (Williamson, 1991; Oxley, 1997). The absence of a fully specified contract means that partner firms also have a greater incentive to work out disputes privately under the equity joint venture, since the courts have less guidance from the partner firms (in the form of a detailed contract) on how to deal with such disputes.[11] These administrative mechanisms ease concerns of opportunism and preserve firm incentives to share

knowledge with partners. Thus, the transaction cost perspective generally predicts that the greater the threat of opportunism, the more likely firms choose more hierarchical organization, such as the equity joint venture.[12]

Clearly, both theories vastly improve our insights into the question of organization form choice. In many cases, both issues of knowledge transfer and control of opportunism potential are important in determining organizational choice. However, if we can identify the situation where the predictions made by each theory for organizational choice diverge, we may be able to better understand why firms exist. An examination of organization choice in R&D alliances presents such an opportunity.

By forming an R&D alliance, firms have explicitly declared their intention to share knowledge or information. Thus, the ease of sharing knowledge is a particularly relevant criterion in organization form choice. Knowledge, particularly tacit knowledge, is often organizationally embedded and, therefore, difficult to transfer across firm boundaries (Teece, 1977; Kogut, 1988). Control, however, is also important since collaboration in R&D raises serious moral hazard concerns. Partners risk 'leakage', or uncompensated transfer of knowledge-based capabilities between partner firms or between the alliance and the partner firms that is outside the spirit of the alliance agreement. This type of behavior is well documented in alliances: Hamel *et al.* (1989) find that firms do well to learn as much from their partners while simultaneously reducing the access of the other partner firms to their own technologies. Choice of organization may alleviate these issues, because organization influences each partner's ability and willingness to share knowledge.

By examining the knowledge bases or portfolios of each partner firm, particularly how much these portfolios differ, we can get an idea of how difficult it is to share knowledge between partners and the extent to which protection against leakage is a concern in a specific alliance. We can then generate hypotheses regarding alliance organizational form choice that differ depending on whether we take a knowledge-based or transaction cost perspective. Thus, I now consider how differences in knowledge portfolios, or 'technological diversity', between partners influences organizational form choice in R&D alliances.

TECHNOLOGICAL DIVERSITY BETWEEN PARTNERS & ORGANIZATION CHOICE: HYPOTHESES

Via R&D collaboration, firms may access unique technologies that are not available in-house. Indeed, this ability to access distinct technologies is often the motivation to collaborate in the first place. However, combining partner technologies or capabilities presents unique coordination challenges. These coordination challenges vary depending upon how diverse (or dissimilar) partner technologies are. Generally, the more a firm's technological expertise differs from its partner(s), the more difficult it will be for the firm to share its expertise with partners and for the firm to benefit from partner expertise. This general premise has implications not only for issues of knowledge transfer within the alliance, but also for issues of control.

We can think of partner technological portfolios along a continuum; at one extreme, partners have identical technological capabilities, where at the other extreme, partners have no similar capabilities (i.e. complete 'diversity'). In most cases, allying firms fall somewhere between these two extremes. However, we expect to see some variation in the level of technological diversity or, alternatively, where allying firms fall along the continuum. As firm capabilities become more diverse (i.e. partner firms have fewer areas of technological expertise in common), coordination difficulties intrude. The ability to benefit from such distinct perspectives in an alliance is not assured.

Allying firms require some capabilities in common (i.e. 'absorptive capacity') to benefit from those not in common (Cohen and Levinthal, 1989, 1990). A firm's absorptive capacity is its ability to 'identify, assimilate and exploit knowledge from the environment,' (Cohen and Levinthal, 1989, 1990: 569). This capacity is developed in a number of ways, including in-house R&D activities. Thus, the breadth of a firm's technological capabilities, or knowledge, determines that firm's ability to share technological capabilities with its partners. It follows that the greater the technological diversity between allying firms, the more each firm has to learn from the other, but the more difficult it is to share knowledge.

The knowledge-based view readily yields predictions for organizational form choice, based on technological diversity between partners. The

equity joint venture, characterized by a common stock of knowledge and organizing principles, facilitates more efficient transfer and/or sharing of complex technologies. Further, with the knowledge substitution effect, firms do not need to fully assimilate their partner's knowledge if the alliance is organized via equity joint venture, since each partner firm has limited powers of fiat over employees of the alliance. Finally, since the equity joint venture facilitates greater flexibility in the face of unanticipated contingencies, this suggests that the equity joint venture leads to less costly adaptation when new opportunities for learning arise. Such flexibility is more likely required when partners have diverse technological portfolios.[13] Thus, applying the knowledge-based view, allying firms more likely choose an equity joint venture for their collaborative R&D activities when partner technological capabilities are diverse.[14]

Transaction cost economics also generates predictions about organizational choice, based on partner technological diversity. The level of technological diversity in an alliance influences both the incentives and the ability of firms to behave opportunistically and, therefore, the threat of leakage in an alliance. As technological capabilities become more diverse among partner firms, each firm has more unique capabilities to lose to the other(s). As such, firm incentives to behave opportunistically rises, since firms have more to gain from such behavior. This suggests that as technological diversity rises, the threat of leakage rises. However, this threat of leakage is mitigated by the need for absorptive capacity (Cohen and Levinthal, 1989, 1990). The need for absorptive capacity limits a firm's ability to misappropriate the technologies of its partner(s). Thus, at higher levels of technological diversity, the threat of leakage is diminished and the need for the safeguards of the equity joint venture decreases.

These arguments suggest two hypotheses: one from knowledge-based arguments and one from transaction cost logic.[15]

H1 (*Knowledge-based view: hypothesis*):

As the diversity of partner firm capabilities increases, the probability that allying firms select an equity joint venture also increases.

H2 (*Transaction cost economics: hypothesis*):

As the diversity of partner firm capabilities increases, the probability that allying firms select an equity joint venture also increases. However, beyond a moderate level of technological diversity, the probability that allying firms select an equity joint venture decreases as technological diversity increases.

EMPIRICAL ANALYSIS

Data & Sample Description

To test the hypotheses above, linking technological diversity with alliance organization choice, I use a dataset describing the alliance activities of firms in the telecommunications equipment industry.[16] The rapid pace of technological development makes this an ideal industry in which to study R&D collaborations. In the late 1980s, the microelectronics and telecom equipment industries converged. A period of rapid technological development followed, changing the nature of competition in the industry. Profitability and survival became critically dependent on a firm's ability to create and commercialize new technologies faster. In response to these increased pressures, firms sought alternatives to purely in house development. R&D alliances represented one such alternative, where firms could spread the risk and cost of technological development. In the telecom equipment industry, firms frequently collaborate in their R&D activities (Pisano *et al*., 1988).

The main source of data is the Securities Data Company (SDC) Database on Alliances and Joint Ventures. The SDC database is compiled from publicly available sources such as SEC filings, news reports, as well as industry and trade journals and contains information on alliances of all types. While SDC has some information on alliances back to 1970, consistent data collection extends from 1988 onwards. Coverage of alliances from 1988 is more comprehensive than pre-1988 alliances. However, coverage is still necessarily incomplete since firms are not required to report their alliance activities. Nevertheless, this database represents one of the most comprehensive sources of information on alliances available and is one of the only public sources available for larger scale empirical studies on alliance activity.[17]

I combine this alliance information with the Micropatent database, which contains information recorded on the front page of every US patent granted since 1975, including inventor and

assignee names as well as patent technological classifications. I use information from this database to construct a firm's patent portfolio. Since we are interested in how well firms can share knowledge with their partners, which depends on the relatedness of this knowledge between partners, it is important to measure each firm's entire technology portfolio. Thus, technological capabilities of the entire firm, rather than a single subsidiary must be measured. Further, since firms do not always assign patents to the subsidiary where the technological expertise was created, a corporate level portfolio is particularly important.[18] To achieve this, I first identify all of the subsidiaries of each firm in the sample via the *Directory of Corporate Affiliations*. Patents assigned to the firm and any of its subsidiaries were then identified for the purposes of constructing the measure of technological diversity, described below.

The sample used to test the hypotheses set out above consists of all domestic R&D alliances formed by firms in the telecom equipment industry during the years 1991–1993, inclusive. Each alliance involves collaborative R&D activities exclusively or in addition to manufacturing, marketing and supply activities. These criteria led to selection of 232 R&D alliances, involving 262 firms. I restrict the sample to domestic alliances to control (in part) for alliance motives. Inclusion of international alliances would likely include alliances with a market access motive, even if these alliances were for collaborative R&D, given that the telecommunication equipment industry is highly regulated. Since the hypotheses developed above are conditional on alliance knowledge sharing motives, reducing the incidence of alternative motives is critical. More controls for alternative motives are set out in the variable descriptions below.

Measures

Dependent variable

Alliance organizational form. Using information from the SDC database, I create a dummy variable to capture alliance organizational form. ORG equals 0 when the alliance is organized by bilateral contract, 1 when organized by equity joint venture. Consistent with the expense and commitment required to set up an equity joint venture, equity joint ventures are the exception rather than the norm. Of the 232 alliances in the sample, 217 are bilateral contracts while 15 are equity joint ventures.

Independent variables

Technological diversity. To capture the diversity of firm technological portfolios, I examine the degree of overlap in the partner firms' patent portfolios. A patent is a document granting exclusive rights to the inventor to produce or use a specific new process or product for a stated time period. In order for a new idea to be patented, the idea must be novel and useful; the invention must pass the scrutiny of the patent office as to its novelty and improvement over existing technology. Extensive research has demonstrated the relationship between patents and various measures of firm performance. Strong, positive relationships exist between patents and new products (Comanor and Scherer, 1969), patents and literature-based invention counts (Basberg, 1982), and non-patentable inventions (Patel and Pavitt, 1997). More recent research shows that patents are strongly correlated with a firm's market value (Hall, 2000).[19]

On the basis of this extensive research, patents seem to be a reasonable proxy for the technological capabilities of the firm. At the very least, patents identify a firm's areas of technological expertise. When a patent is granted, the underlying technology must be classified according to the US patent classification system.[20] This classification system provides a means to identify the underlying technologies owned by each partner firm. From this, we can examine the partner firms' technological differences (or similarities) and construct a reliable measure of technological diversity between partner firms (Jaffe, 1986).

First, I generate each partner firm's technological portfolio by measuring the distribution of that firm's patents across patent classifications, year by year. This distribution is captured by a multidimensional vector, $F_i = (F_i^1 \ldots F_i^s)$, where F_i^s represents the number of patents assigned to partner firm i in patent class s. Diversity of partner firm capabilities is then:

$$\text{Technological diversity} = 1 - \frac{F_i F_{i'}'}{\sqrt{(F_i F_i')(F_{i'} F_{i'}')}},$$

where $i \neq i'$.[21] Technological diversity varies from zero to one: a value of zero indicates complete similarity of technological expertise, while a value

of one indicates the greatest possible technological diversity between partner firms. This diversity measure normalizes the length of the within-class vectors to one and essentially captures the angle between the firm vectors. This means that the measure is not sensitive to the number of patents within a class.[22] To capture the possible non-linear relationship between technological diversity and alliance organization choice, I also include the square of technological diversity.

Control variables

Several other empirical studies have examined organizational form choice in alliances generally. To captures other factors found to be relevant in alliance organization selection, I include several control variables. Oxley (1997) argues that alliance characteristics that make an alliance agreement more difficult to specify, monitor and enforce increase the probability that an equity joint venture will be selected. Many R&D alliances involve not only joint R&D, but manufacturing, marketing and/or supply activities as well. As the number of different activities taking place within an alliance increases, specification becomes more complicated. Monitoring becomes more difficult as alliance activities become more complex. Project complexity increases as alliance scope and/or the number of partner firms involved increases. More complex or uncertain tasks demand a greater share of the limited supply of managerial attention than do simple activities with relatively certain trajectories (Masten *et al*., 1991). Using this framework, I include several variables that make bilateral contracts more costly relative to the equity joint venture.

Narrow, intermediate or broad R&D activities. R&D activities range from very narrow projects, such as those involving development of new products or processes based on existing technology, to very broad, ambitious projects where firms seek to develop the 'next generation' of a particular product. Oxley (1997) finds that fully specifying a contract and effectively monitoring compliance is more difficult when the alliance involves more than one technology or product line. I include a similar measure, which captures the breadth of collaborative R&D activities. This measure is based on the synopses of alliance activity provided by the SDC database.

An alliance is categorized as having narrow R&D activities when alliance activities are focused on development of new products or processes based on existing technologies. This includes, for example, the alliance between 3 M and IBM to jointly develop 3M's 'Ecart' 2.4 GB tape cartridges for IBM tape products. The base technology exists, 3M's Ecart tape cartridges, and needs only to be customized to a new user, IBM. Alliance R&D activities are intermediate when the base technology for a product exists, but activities go beyond mere customization for a new market. The alliance between Hewlett-Packard and IBM to jointly develop and manufacture fiber optic components designed to provide high speed fiber optical communications between computers is an example in this category. The base technology, i.e. fiber optic components, exists, but requires more than mere customization for a new user. Finally, when collaborative projects are aimed at developing 'next generation' technology, alliance scope is broad. A base technology may exist, but radical changes are sought. The alliance between Fujitsu and Analog Devices for the development of 'next-generation' integrated circuits is an example that falls within this category. Note that I omit the dummy capturing intermediate R&D activities from the analysis, since alliances with intermediate R&D activities are the most represented category.[23]

Multilateral alliance. Having more than two partner firms in a particular alliance likely makes monitoring more difficult (Oxley, 1997). To capture this hypothesized effect, I include a dummy, Multilateral Alliance, which equals one if the number of partner firms in an alliance exceeds two, zero otherwise.[24]

Breadth of alliance activities. The breadth of alliance activities refers to activities in addition to joint R&D. Above, I describe a measure to capture the breadth of collaborative R&D activities; here, I measure the breadth of *alliance* activities, which captures whether alliance activities go beyond joint R&D. For example, an alliance involving manufacturing or marketing in addition to the joint R&D activities is considered broader than an alliance involving only R&D activities. 'Breadth of alliance activities' is set to one when alliance activities include manufacturing, marketing and/or supply in addition to collaborative R&D. I expect contract specification and monitoring become

more difficult when alliance activities go beyond joint R&D.

Several other variables that influence alliance organization are suggested either by the prior empirical literature or general inference from the incentive alignment literature. For example, Gulati (1995) suggests that prior and concurrent ties between partner firms operate to reduce threats of opportunism and, as such, reduce the need for more hierarchical organization. To control for this effect, I include a measure of all prior and concurrent alliances among partner firms. This measure is the number of prior and concurrent ties between partner firms in the focal alliance.

I also include a measure of allying firms' general reputation. As firms generally prefer to transact with other firms of known reputation (Granovetter, 1985), we infer that partner firms with many previous alliances have a positive reputation. These prior alliances may aid incentive alignment; allying firms may forbear from opportunistic behavior if they anticipate that their reputation may be damaged as a result. To construct this measure, I first add all prior alliances for each partner firm reported in the SDC database. A firm's reputation effect is then the lowest number of prior alliances for all partner firms. I take the lowest common denominator as I expect reputation to deter opportunism only when it is mutual.[25]

RESULTS

Table 1 presents descriptive statistics for all variables. The average alliance in the sample has intermediate R&D activities (i.e. beyond simple customization of existing technology to new uses, but not to next generation development), involves only two firms, and is only for collaborative R&D (i.e. no manufacturing, marketing or supply). The average firm in these alliances has some prior alliance experience and some prior experience, but little technological overlap, with its current partner.

To test the relationship between technological diversity between partners and alliance organization selection, I use a binomial probit model. Under the probit model, the probability that allying firms select an equity joint venture or bilateral contract is modeled as a function of alliance specific variables. Two specifications are estimated—these results are set out in Table 2. Column (1) includes technological diversity as well as measures suggested from prior studies on

Table 1. Descriptive Statistics and Pearson Correlation Coefficients

Correlations (correlation, significance)	1	2	3	4	5	6	7	8	9
1 Alliance organizational form	1.000								
2 Technological diversity	0.001	1.000							
	0.987								
3 Technological diversity, squared	−0.019	0.994	1.000						
	0.771	0.000							
4 Narrow R&D activities	−0.115	0.028	0.034	1.000					
	0.081	0.670	0.608						
5 Broad R&D activities	0.251	−0.057	−0.067	−0.287	1.000				
	0.000	0.388	0.307	0.000					
6 Multilateral alliance	0.149	−0.223	−0.235	−0.182	0.239	1.000			
	0.023	0.001	0.000	0.006	0.000				
7 Breadth of alliance activities	0.076	−0.083	−0.084	0.242	−0.065	−0.193	1.000		
	0.249	0.211	0.200	0.000	0.322	0.003			
8 Prior and concurrent alliances	−0.033	−0.439	−0.427	−0.016	0.054	0.301	0.011	1.000	
	0.619	0.000	0.000	0.807	0.417	0.000	0.868		
9 General firm reputation	−0.020	−0.211	−0.226	0.078	−0.061	0.228	0.089	0.236	1.000
	0.762	0.001	0.0001	0.236	0.358	0.001	0.176	0.000	
Mean	0.065	0.939	0.904	0.341	0.138	0.138	0.392	1.555	4.599
Median	0.000	1.000	1.000	0.000	0.000	0.000	0.000	1.000	2.000
Minimum	0.000	0.245	0.060	0.000	0.000	0.000	0.000	0.000	1.000
Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	4.000	50.000
Std. Dev.	0.246	0.146	0.217	0.475	0.346	0.346	0.489	0.710	7.889

$n = 332$

Table 2. Determinants of Organizational Form Selection[a]

Variable	Pr(Organization = Equity joint venture) (1)	(2)
Technological diversity	141.944***	130.621**
	(69.026)	(71.101)
Technological diversity, squared	−80.783***	−74.912**
	(37.965)	(38.926)
Narrow R&D activities	−0.420	−0.409
	(0.411)	(0.410)
Broad R&D activities	0.688**	0.645**
	(0.355)	(0.366)
Multilateral alliance	0.233	0.316
	(0.421)	(0.445)
Breadth of alliance activities	0.757***	0.785***
	(0.332)	(0.337)
Prior alliances with partner		−0.176
		(0.312)
General firm reputation		−0.006
		(0.023)
Constant	−63.350***	−57.722**
	(31.205)	(32.361)
n	232	232
Log *L*	−41	−41
Chi squared	28.29***	28.69***
d.o.f	6	8
% Correct	93.5	93.1

*$p<0.05$. **$p<0.01$.***$p<0.001$. Standard errors in parentheses.
[a] Probit regression model. Dependent variable is organizational form. Positive coefficients indicate a greater likelihood of choosing an equity joint venture.

alliance organization choice that predict the costs of using a bilateral contract relative to an equity joint venture and (2) adds other alliance controls suggested by prior empirical studies to affect alliance organization choice.

For both models tested, the chi-square values are significant, indicating the models are a substantial improvement over the intercept only model.[26] The models predict actual organizational form chosen in over 93% of the cases. This predictive power is about the same as the simple assignment of the all predicted outcomes to the bilateral contract category (93.5%).

An initial inspection of the results in Table 2 shows general support for both the knowledge-based and transaction cost hypotheses—increasing technological diversity increases the probability that allying firms choose an equity joint venture. As firms have less technological expertise in common with their partners, they are more likely to choose an equity joint venture. This result is robust across both specifications and is consistent with the hypothesis that more hierarchical organization makes knowledge sharing between partners easier and facilitates coordinated responses to unanticipated learning opportunities over the course of the alliance. The more diverse a firm is from its partner(s) in terms of technological expertise, the greater the need for enhanced knowledge transfer and flexibility over the course of the alliance. In this sense, firms appear to choose alliance organization in response to knowledge flow considerations. Control, however, appears also to be important. Allying firms anticipate the increased risk of leakage when partner technologies differ. In response, these firms more frequently opt for the equity joint venture, since this mode reduces the incentives and ability of partners to behave opportunistically. Thus, the data supports the proposition that both knowledge flow and control of opportunistic behavior are determinants of organization choice.

At higher levels of technological diversity, however, the results suggest a slightly different story—the relationship between technological diversity and organization choice reverses in sign. The coefficient on technological diversity, squared, is negative and significant across all specifications. Initially, rising diversity increases the probability of equity joint venture selection but, beyond a

certain level of diversity (0.88), this relationship turns negative.[27] Technological diversity beyond this maximum point actually decreases the probability that an equity joint venture is selected.[28]

To better illustrate the relationship between technological diversity and organization choice, I calculate the expected probability that partners select an equity joint venture at all levels of technological diversity. First, I take the estimates from Table 2 and evaluate these estimates at the median values of the independent variables. I then calculate the expected probability over all values of technological diversity in the sample—from 0.245 to 1. These calculations are graphed in Figure 1. This figure shows two curves: one for estimates from each column of results in Table 2.

The figure shows definitively that technological diversity bears a non-monotonic relationship with alliance organization choice. Allying firms more likely select an equity joint venture as their technology portfolios, or knowledge bases, diverge. Beyond a relatively high level of diversity, though, firms are much less likely to choose an equity joint venture. The fact that this effect reverses as partner technologies become more diverse lends empirical support to the absorptive capacity argument (Cohen and Levinthal, 1989, 1990); firms require some technologies in common in order to utilize technologies outside the firm. It follows that firms require some overlap with their partners to misappropriate technologies—the threat of leakage decreases as technological diversity increases. The need for safeguards against opportunistic behavior is diminished. This finding suggests support for the transaction cost hypothesis (H2) over the knowledge-based hypothesis (H1).

The remaining coefficient estimates in Table 2 are largely consistent with expectations. In specification (1), the equity joint venture is chosen more frequently where alliance activities include manufacturing, marketing or supply in addition to joint R&D. This result is robust across specifications and is consistent with the findings of Pisano (1989) and Oxley (1997). Pisano (1989) finds that alliances involving activities in addition to R&D are more likely to use equity links than are alliances involving R&D alone. Similarly, Oxley (1997) finds that 'mixed' transactions, that is, those alliances that involve more than one type of activity, increase the need for more hierarchical alliance organization. However, while we expect that alliances involving more than two partner firms are more likely to be structured as an equity joint venture, the coefficient estimate on Multilateral Alliance is not statistically significant.

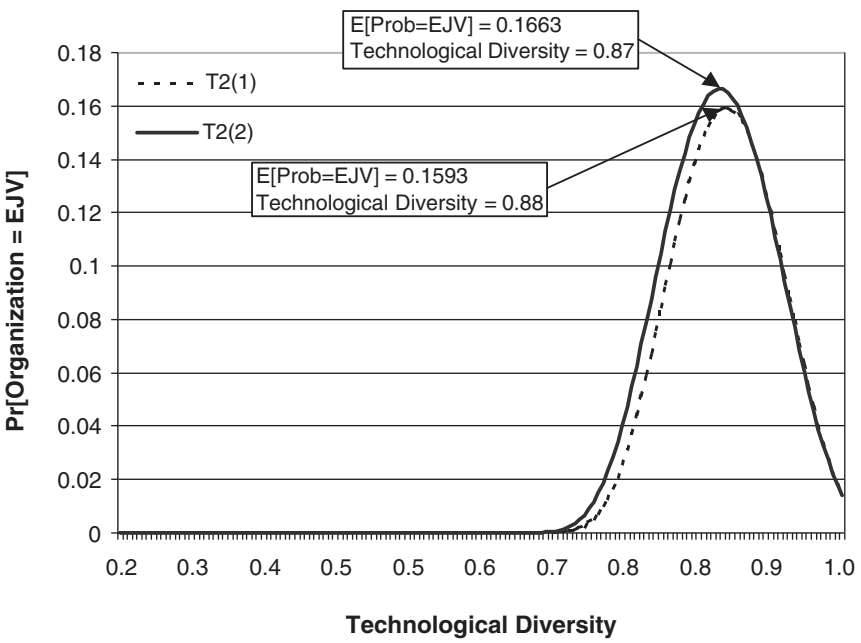

Figure 1. The effect of technological diversity on organisation choice.

The breadth of R&D activities influences alliance organization selection as expected. Broad R&D activities increase the probability that an equity joint venture is selected. This result is consistent with Oxley (1997), who finds that firms in alliances with a broader technology scope anticipate greater monitoring difficulties and, therefore, select more hierarchical organization. Narrow R&D activities, however, do not appear to significantly reduce the probability that an equity joint venture is selected. Coefficients on the remaining two control variables—prior alliances with a partner and general firm reputation—are as expected, though neither is significantly different from zero.[29]

From Table 2, I conclude that allying firms more likely choose an equity joint venture for their alliance activities as partner technological expertise diverges. Knowledge transfer and coordination among partners is more difficult when firms have fewer areas of common technological expertise. The equity joint venture, with its enhanced ability to facilitate knowledge transfer and safeguard against leakage, is the preferred choice of alliance organization as technological diversity increases. However, it appears that at higher levels of technological diversity, the diminished need for control drives organization selection and partners are less likely to select an equity joint venture.

When firm knowledge bases are highly diverse, threats of leakage diminish because of the lack of absorptive capacity, yet the need for enhanced communication and knowledge transfer mechanisms arguably remains undiminished. Predictions from the knowledge-based and transaction cost perspectives thus diverge. Results here suggest that opportunism-based concerns dominate knowledge transfer concerns. This finding raises an important question: are knowledge sharing and communicating mechanisms inextricably entwined with organizational form or are such mechanisms and organizational form separable? Perhaps Foss (1996: 473) is correct when he argues that, in the absence of opportunism,

> '*the gains from resources/assets being embedded in higher order organizing principles could be realized over* the market. *Agents (human resources) could simply meet under the same factory roof, own their own pieces of physical capital equipment or rent it to each other, and develop value-enhancing higher order organizing principles among themselves (as a team). In the absence of opportunism/moral hazard, the degree of co-specialization among the various resources would carry no implications for ownership*.' [emphasis in original]

At least in the context presented here, these results suggest that even in situations where knowledge transfer costs are presumably high, the lack of the threat of opportunism means that an alliance organization form closer to market is adequate. Firms may be able to develop efficient knowledge transfer and communication mechanisms independent of organizational form.

DISCUSSION & CONCLUSION

Firms entering into R&D alliances face considerable challenges; partners must be able to transfer complex knowledge and skills with partners and/or communicate about idiosyncratic stages of the R&D process. R&D collaboration, however, also raises the risk of leakage or unintended transfer of knowledge and skills between partners. Since firms often do not wish to make better competitors of their partners, the ability to safeguard against leakage is critical. Alliance organizational form represents one means of both improving knowledge flows and safeguarding against leakage. In this paper, I examine alliance organization choice by applying knowledge-based and transaction cost perspectives. While this examination of organization choice alone is a worthy exercise (see, e.g. Pisano, 1989; Oxley, 1997), the study of such choice in the context of R&D alliances presents a unique opportunity to explore the tension between the knowledge-based and transaction cost perspectives.

The ability to share knowledge and safeguard against leakage are likely important to some extent in all R&D alliances; however, these issues take on greater importance in alliances where partners have very different areas of technological expertise. The ability to share very diverse capabilities is quite difficult, given that firms require some technologies in common to assimilate or utilize those not in common (i.e. firms require absorptive capacity). While the lack of common knowledge

bases may hinder knowledge sharing efforts, a lack of absorptive capacity also has the effect of reducing unintended knowledge transfer, or leakage. Because very diverse knowledge is difficult to share, but also unlikely to be unintentionally transferred, the predictions for alliance organization choice under the knowledge-based and transaction cost perspectives diverge.

According to the knowledge-based view, more hierarchical organization (such as the equity joint venture) is characterized by a common stock of knowledge and organizing principles. As a result, the equity joint venture facilitates more efficient transfer and/or sharing of complex technologies. This suggests that allying firms more likely choose an equity joint venture for their collaborative R&D activities when partner technological capabilities are diverse. In contrast, the transaction cost perspective highlights the monitoring, control and adaptation features of more hierarchical organization. Applying this perspective, more hierarchical organization facilitates greater monitoring and safeguards against the threat of leakage. As such, firms more likely choose an equity joint venture as partner technologies become more diverse because firms have more to lose to their partners in this case. However, at higher levels of diversity, the lack of absorptive capacity reduces the risk of leakage and, therefore, the need for increased monitoring and control mechanisms of the equity joint venture decrease. With a sample of 232 R&D alliances in the telecom equipment industry, I find more thorough support for the transaction cost hypothesis. Initially, as the diversity of partner technology portfolios rises, that is, partners have less technological expertise in common, allying firms more likely choose an equity joint venture. However, at higher levels of technological diversity, this relationship reverses and allying firms are less likely to choose the equity joint venture.

To now, there has been a substantial debate between the knowledge-based and transaction cost literatures as to the role of opportunism in determining choice of organizational form (see, e.g. Ghoshal and Moran, 1996; Williamson, 1996). While some studies argue that opportunism or, more broadly, transaction costs do not drive selection of organization (Kogut and Zander, 1992, 1993; Ghoshal and Moran, 1996), results here suggest that when concerns over opportunism are low, firms are less likely to choose more hierarchical organization even though the need for enhanced knowledge flow is undiminished. In this sense, opportunism or moral hazard issues appear to have greater explanatory power at least in the context of alliance organization choice.

Naturally, the greatest limitation to this work is that it examines organization choice in a single context—R&D alliances in the telecommunications equipment industry. It is not possible to say whether these results arise out of idiosyncrasies in the setting or whether the finding is robust across contexts. A useful extension to this work would be to find other empirical contexts where organization choice predictions diverge between the two perspectives, i.e. where opportunism threats are low, but the need for enhanced knowledge transfer and communication mechanisms is high. With further extensions to this work, we may be able to identify the mechanisms and characteristics that are not separable from organizational form and, ultimately, the true nature of the firm.

Acknowledgements

I thank Will Mitchell, Andy King, Bernard Yeung, and an anonymous reviewer for helpful comments on this paper. All remaining errors are my own.

NOTES

1. For example, see Link and Bauer (1989), Arora and Gambardella (1990), Kamien *et al.* (1992), and Tripsas *et al.* (1995). Other cited benefits include risk management and access to a wider know-how network (Tripsas *et al.*, 1995: 369).
2. See, for example, Conner and Prahalad (1996; 489), which sets out the predictions for governance choice according to knowledge-based and transaction cost theories. In three out of four cases considered, knowledge-based and transaction cost economics theories generate similar predictions for the choice of governance.
3. For a more thorough discussion of the different forms the alliance organization may take, see Powell (1990) and Contractor and Lorange (1988).
4. Here, I examine only bilateral (or multilateral) forms of alliance organization, since my focus is alliances for collaborative R&D where two or more firms pool their talents to reap mutual gains. More unilateral forms of collaboration, such as licensing agreements, present different coordination issues and are beyond the scope of this paper.
5. For example, the following provision is made in a joint venture agreement between SICPA Industries and Flex Products:

'*2.2 DESIGNATION OF PROJECTS. Specific tasks to be undertaken by SICPA Industries and Flex shall be determined by the unanimous vote of the committee. Neither SICPA Industries ... nor Flex... shall have any obligation to perform tasks or projects except as authorized and directed by a unanimous vote of the Committee*.' (Source: SEC 10 K filings).

In this case, the 'Committee' is the joint venture governing body consisting of equal numbers of members from Flex Products and SICPA Industries. Both firms have the explicit right of veto over any activities of the joint venture.

6. For example, in Killing's (1983) study of Mexican joint ventures, eight out of ten general managers were on the payroll of the joint venture, rather than the parent. In only four out of ten ventures was the general manager's bonus tied to one parent's results. Less senior employees are even less likely to be officially tied to a specific parent.
7. Of course, to the extent that employees rotate back to parent firms, incentives to act in the best interests of the joint venture rather than the parent may be curtailed. Such incentives may be further attenuated if employees seek to gain employment with the other partner firm. Joint venture agreement terms, however, often preclude a firm from hiring its partner's employees that are working for the venture.
8. For a more thorough discussion of the governance and organization features of the equity joint venture, see Oxley (1997).
9. Conner (1991: 140) similarly argues that, 'firms have advantages over market relationships in the joint activity of creating and redeploying specific capital.'
10. 'For transactions which are the product of complex organizational routines, the transfer of know-how can be severely impaired unless the organization is itself replicated' (Kogut, 1988: 323).
11. In cases where a coordinated response to these unanticipated contingencies is desirable, legalistic enforcement of agreement terms can lead to inefficient outcomes. Legalistic enforcement is inefficient when general rules are applied to disputes over which subject matter, industry characteristics and/or intention of the parties the courts have limited knowledge.
12. 'The variety of administrative controls and monitoring rights found in equity joint ventures,... mean that equity joint ventures lie closest to the hierarchy end of this 'market-hierarchy continuum' of alliance forms' (Oxley, 1997: 392).
13. Conner and Prahalad (1996: 487) argue that contract renegotiation costs, i.e. adjustment costs, increase with the continuing degree of difference in perspectives between the parties. As the perspectives of the parties become more diverse, therefore, the likelihood that more hierarchical organization is required increases. This argument is analogous to the transaction cost perspective; the prospect of costly renegotiation and haggling ex-post often makes hierarchy a less costly organizational alternative (Williamson, 1985). In this sense, the arguments for internal organization that are truly unique to the knowledge-based perspective are the knowledge substitution effect and the reduction in communication costs.
14. This argument assumes that firms wish to access their partner's highly diverse knowledge. If this is not the case, then we may not expect to see the monotonic relationship between technological diversity and selection of equity joint ventures at high levels of diversity. However, in the empirical analyses below, I control for the purpose of the alliance to capture different alliance motives, which likely correlates with a firm's desire to access its partners' diverse capabilities.
15. Note that the situation I have highlighted here—that is, where the knowledge-based and transaction cost perspectives generate divergent hypotheses—is precisely the situation anticipated by Conner and Prahalad (1996). Conner and Prahalad (1996: 489) argue that divergent hypotheses are possible where potential opportunism is low, but the need for the enhanced communication and knowledge substitution mechanisms of more hierarchical organization persists.
16. I define the telecom equipment industry via three SIC classes: 3661, 3663, and 3669.
17. Recent studies that have used the SDC data include Anand and Khanna (2000) and Sampson (1999).
18. Within the sampled firms, I find that 73% of patents are assigned to the ultimate parent firm, while 27% are assigned to various levels of subsidiaries.
19. For a more thorough review on the use of patents as a measure of technological capabilities, see Ahuja (2000).
20. Patents are also classified according to the international patent classification system (IPC). However, since I am using US patents here for this analysis, I rely on the US patent classification system.
21. Note that this measure calculates technological diversity as between a pair of firms. For alliances involving more than two firms, I calculate this measure for every combinatorial pair of firms in the alliance and take the average of these measures.
22. This measure is preferable to one that captures the depth of patents within class, since such a measure would show similar technological differences between, for example, Intel and a small microprocessor manufacturer (with presumably few patents) and between Intel and General Motors.
23. To some extent, this variable also controls for alliance motives. For example, we might expect that broad R&D activities such as the development of next generation integrated circuits require greater knowledge sharing between partners than narrow R&D activities.
24. Note that 82% of all R&D alliances in the sample involve only two partner firms. Of the remaining alliances, 9.5% involve three firms, 3% involve four and the remaining 5.5% involve anywhere from five to twelve partner firms.

25. This variable may also be thought of as a proxy for the partners' prior alliance experience with other firms. The effect of such experience on organization choice, however, is ambiguous.
26. Logit analyses of the three models show virtually identical results to those in Table 2.
27. $\frac{\partial Pr(Organization=Equity\ Joint\ Venture)}{\partial Technological\ Diversity} = 0$ when technological diversity = 0.88 (column (1)). This maximum point for column (2) is 0.87.
28. While technological diversity, up to the value of 0.88 increases the probability that an equity joint venture is selected, many alliances in the sample have diversity greater than 0.88. 75% of alliances in the sample (174 out of 232) have diversity equal to 1. This means that many alliances involve firms with no patent class overlap. For these alliances, this level of technological diversity means the probability of equity joint venture selection is reduced. An alternative approach that would likely yield greater variation in the technological diversity measure would be to group multiple patent classes together as described in Jaffe (1986). However, such a categorization inevitably involves a subjective assessment as to the logical groups for patent classes. As Hall *et al*. (2001: 13) note with respect to assigning patents to aggregate technology categories: 'there is always an element of arbitrariness in devising an aggregation system and in assigning the patent classes into the various technological categories, and there is no guarantee that the resulting classification is 'right', or adequate for most uses.'
29. This contrasts with the prior empirical results of Gulati (1995), who found that prior and concurrent alliances decreased the need for more hierarchical organization.

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