Strategic Management Journal
Strat. Mgmt. J., **24**: 1209–1229 (2003)
Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/smj.353

ALLIANCE FORM: A TEST OF THE CONTRACTUAL AND COMPETENCE PERSPECTIVES

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This paper analyzes factors that influence firms' choice of the organizational form of strategic alliances. I consider arguments suggested by both the contractual and the competence perspectives. In order to distinguish empirically between them, I devote special attention to the role played by the similarity of partner firms' technological specialization. In the empirical section I consider a sample composed of 271 equity joint ventures, non-equity bilateral and unilateral agreements established between each other in the period 1983–86 by 67 North American, European, and Japanese enterprises from the world's largest firms in information technology industries. I examine the effects on the choice of alliance form of a measure of firms' technological proximity based on patents count, while controlling for other variables that are usually considered in the empirical literature. The estimates of binomial and multinomial logit models support the competence-based argument that in technological alliances divergence in partners' technological specialization results in a higher propensity to use equity forms. Overall, the findings suggest that both the contractual and competence perspectives provide valuable complementary insights into the determinants of alliance form. Copyright © 2003 John Wiley & Sons, Ltd.

INTRODUCTION

In the economic and managerial literature interest in strategic alliances between firms dates back to the late 1970s and early 1980s (see, for instance, Pfeffer and Nowak, 1976; Berg, Duncan, and Friedman, 1982; Mariti and Smiley, 1983; Harrigan, 1985; Hladik, 1985). More recently, increasing attention has been drawn to the organizational form of alliances. A number of empirical studies (Pisano, Russo, and Teece, 1988; Pisano, 1989; Gulati, 1995; Garcia Canal, 1996; Oxley, 1997, 1999a; Gulati and Singh, 1998), mainly inspired by transaction cost economics (TCE; see Williamson, 1975, 1985) and other contractual approaches, have analyzed the choice between equity forms (i.e., joint ventures and acquisitions of minority shareholdings) and contractual (i.e., non-equity) arrangements. TCE argues that firms resort to equity agreements in order to economize on transaction costs when there is a non-negligible risk of opportunism, but not so much as to mandate hierarchical internalization; otherwise less expensive non-equity modes are used (Hennart, 1988; Kogut, 1988; Williamson, 1991). Accordingly, authors inspired by TCE contend that equity forms are relatively more suitable for complex alliances (i.e., those that link together several partners and/or have broad product, technology, or activity scope) and for alliances that have a technological component. As to this latter alliance category, equity modes allegedly allow firms to deal

Key words: alliances; learning; transaction costs; real option theory
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Received 18 January 2000
Final revision received 2 May 2003

more effectively with the contractual and appropriability hazards inherent in the development, transfer, and exploitation of technological knowledge, due to the incentive alignment properties of shared ownership and the superior monitoring and control mechanisms provided by an autonomous formal managerial hierarchy. Previous empirical studies generally lend support to such predictions (see Pisano *et al.*, 1988; Pisano, 1989; Osborn and Baughn, 1990; Gulati, 1995; Garcia Canal, 1996; Gulati and Singh, 1998; Oxley 1997, 1999a).

Nevertheless, one major weakness of the TCE construct in the alliance domain is that it overemphasizes individual parties' minimization of transaction costs, while holding other factors constant. In this work I adhere to the view that the choice of alliance form is driven by considerations based on joint value maximization (Zajac and Olsen, 1993). In particular, firms jointly decide the amount of relation-specific investments they will commit to a collaboration depending on the motives they are pursuing and the characteristics of partners so as to maximize the expected pay-off of the alliance. In turn, in accordance with TCE such decision crucially influences the choice of alliance form.

While there are several motives leading to the formation of alliances (Harrigan, 1988; Hagedoorn, 1993; Glaister and Buckley, 1996), authors in the competence perspective contend that alliances are often aimed at expanding a firm's set of distinctive capabilities through interorganizational learning; this especially applies to alliances that involve technological activities (Kogut, 1988; Hamel, 1991; Hodgson, 1998; Loasby, 1998). In order to effectively support learning processes, alliance partners rely on sophisticated coordination mechanisms that involve substantial relation-specific investments. Thus they will preferably resort to equity modes as such forms are less vulnerable to opportunistic behavior.

The above discussion highlights the complementarity between the contractual and the competence perspectives as regards the governance mode of alliances. It also makes evident that it is quite difficult to distinguish empirically between them, as they often have coincident predictions. In fact, both perspectives expect equity forms to be relatively more frequent in technological alliances. The present paper aims to extend our understanding of the relative explanatory power of the two approaches. For this purpose, I consider the impact on alliance form of the overlap of partners' knowledge base, measured by the proximity of their technological competencies. As will be argued later in greater detail, the prediction of the contractual approach as to the impact of such factor is ambiguous. On the one hand, if alliance partners have similar technological specialization, there are greater appropriability hazards as there is greater risk of unintended leakage of technical knowledge to partners. On the other, contractual hazards and the associated 'hold-up' problems are reduced; in fact, it is easier for firms both to consider *ex ante* future contingencies and to monitor *ex post* partners' actions, thus leaving less room for opportunistic behavior. As greater technological overlap may lead to either an increase or a decrease of transaction costs, it is not clear whether it will favor use of equity or non-equity forms. On the contrary, the competence-based argument is straightforward. If partners have developed technological expertise in the same fields, mutual learning will be easier with all else equal, as firms are better able to absorb each other's knowledge. Under such circumstances, the need for sophisticated coordination mechanisms and the amount of the associated relation-specific investments are considerably reduced and so is the likelihood of resorting to equity modes.

In the empirical section of the paper I consider a sample composed of 271 alliances established between each other in the period 1983–86 by 67 North American, European, and Japanese enterprises from the world's largest firms in information technology industries. I first distinguish equity joint ventures and contractual (i.e., non-equity) forms. Then following some recent studies (Garcia Canal, 1996; Mowery, Oxley, and Silverman, 1996; Oxley, 1997, 1999a; Cantwell and Colombo, 2000), I make a further distinction between non-equity bilateral and unilateral (i.e., quasi-market) forms. Bilateral contractual forms (i.e., joint R&D agreements, technology sharing agreements, cross-licenses, co-marketing agreements and other arrangements aimed at sharing production and/or distribution facilities) generally incorporate some of the coordination and incentive aligning mechanisms typical of equity forms, such as the creation of a dedicated managerial hierarchy, joint work teams and mutual exchange of hostages (see Oxley, 1997: 392). On the contrary, such controls are absent in unilateral arrangements such as licenses, supply agreements, R&D contracts, technology transfer agreements, and other unilateral commercial agreements.

I estimate binomial and multinomial logit models. I rely on a set of explanatory variables that in addition to variables already considered by previous empirical studies includes a measure of the technological proximity of firms based on patents count. Overall, the empirical findings suggest that both the contractual and competence perspectives provide valuable complementary insights into the determinants of alliance form. In particular, the probability that a technological collaboration is an equity joint venture turns out to be greater the more dissimilar the knowledge base of partner firms. Such a result is peculiar to the competence-based approach; it suggests that as was already pointed out by Simonin (1999), in technological alliances the 'absorptive capacity' of partners (Cohen and Levinthal, 1990) substitutes for commitment of relation-specific resources in supporting mutual learning processes. The results of the econometric estimates also confirm some of the arguments of TCE; in particular, complex relations which are exposed to greater risk of opportunism are found to be prevalently governed through equity forms. Nonetheless, they also show that, contrary to the predictions of both TCE and the competence perspective, when collaborations have a technological component, bilateral contractual modes are more popular than both equity joint ventures and non-equity quasi-market arrangements. This result points to the importance to take into due account the trade-off between commitment of relation-specific resources and flexibility, as is contended by the literature inspired by real option theory (see, for instance, Chi and McGuire, 1996; Folta, 1998; Chi, 2000).

In the next section the theoretical hypotheses are developed. In particular, I consider the effects on the choice of alliance form of the similarity of partners' technological specialization and I contrast the arguments associated with TCE from one side, and the competence perspective from the other. The insights of real option theory are also considered. The data set is then presented, followed by specification of the econometric models, a description of the explanatory variables and a discussion of their predicted sign. The subsequent two sections are devoted to presentation of the empirical findings and discussion of their implications for theory. Some summarizing remarks conclude the paper.

THEORETICAL HYPOTHESES

In this paper I adhere to the view that alliance formation is driven by joint value maximization (Zajac and Olsen, 1993). Accordingly, alliances are established when the net present value of the pay-off partners expect from the collaboration—that is, the difference between the revenues and the production and transaction costs of the collaboration—exceeds that of proceeding alone. Following a similar reasoning, partners will cooperatively choose the organizational form that maximizes the net present value of the pay-off of the alliance.

In the literature it is widely recognized that alliances may be formed for very different motives (Mariti and Smiley, 1983; Harrigan, 1985; Contractor and Lorange, 1988; Hagedoorn, 1993; Glaister and Buckley, 1996). These include efficiency reasons (e.g., costs and risk sharing, mutual specialization of tasks, consolidation of production capacity), competitive reasons connected with collusion and other moves aimed at reducing rivalry (e.g., teaming up with a competitor, exerting market power on customers and suppliers, heightening entry barriers through the definition of a new standard), and strategic reasons (e.g., getting a toehold in a growing business, entry into a new geographic market, exit, developing new capabilities). Depending on the specific motives, some organizational forms may be more suitable than others to increase the revenues and/or reduce the costs of an alliance; in other words, the logic of the alliance is likely to influence the choice of the organizational form, even though the empirical evidence on this issue is rather weak (see, for instance, Glaister and Buckley, 1996). More specifically, the greater the commitment of relation-specific resources needed to pursue the objectives and obtain the benefits of an alliance, the more likely that the alliance will have an equity form so as to reduce the associated transaction costs.

Authors within the competence perspective (Winter, 1987; Prahalad and Hamel, 1990; Conner and Prahalad, 1996; Grant, 1996; Teece, Pisano, and Shuen, 1997; Hodgson, 1998; Loasby, 1998) have pointed out that strategic alliances often are instrumental to extending a firm's collection of distinctive capabilities through inter-organizational learning (Kogut, 1988; Hamel, 1991; Parkhe, 1991; Teece and Pisano, 1994; Powell, Koput, and Smith-Doerr, 1996; Inkpen and

Dinur, 1998; Khanna, Gulati, and Nohria, 1998, 2000; Nagarajan and Mitchell, 1998; Dussauge, Garrette, and Mitchell, 2000. For an antecedent see Richardson, 1972: 889).

In this paper the term 'inter-organizational learning' refers to any addition to a firm's set of capabilities obtained through interaction with alliance partners. On the one hand, the competence-based approach emphasizes the unique advantages of the fusion of knowledge possessed by different organizations. It is argued that individuals have context-specific path-dependent 'cognitive frames' that are developed in interaction with the physical and social environment (Nooteboom, 1992, 2004). Within firms individuals' cognitive frames are largely shared, providing guidance and limits to the search directions firms pursue in their autonomous innovative activity (Nelson and Winter, 1982; Grant, 1996). Exposure to partners' cognitive frames may yield novel insights, as firms benefit from 'external economies of cognitive scope' (Nooteboom, 1992, 1999). This means that the pooling of partners' knowledge in an alliance may result in the joint development of new capabilities that could not be created in isolation, with the associated synergistic gains being shared by partners (Khanna *et al.*, 1998, 2000; Colombo, 1999; Nooteboom, 1999). On the other hand, an alliance may simply be instrumental to transferring existing knowledge from one firm to another, thus allowing the recipient firm to internalize partner's capabilities and to use them in its own operations (Khanna *et al.*, 1998).[1]

Nevertheless, as was said earlier, learning is just one of the possible motives of an alliance. Whether learning is a key driver or not depends among other factors on the characteristics of the alliance's underlying operations. Previous empirical studies clearly indicate that *technological alliances* are more often oriented towards inter-organizational learning than alliances that do not have a technological component. Sakakibara (1997a, 1997b) analyze the motivations of Japanese firms in participating in government-sponsored R&D consortia and show that firms perceive obtaining complementary knowledge and sharing specialized skills as the most important objectives of such projects. Similarly, Brockhoff, Gupta, and Rotering (1991) found that the possibility of capturing synergistic gains from the exchange of complementary technical knowledge is the most important reason for cooperative R&D in Germany. According to data from the CATI database, technology complementarity is the most frequent motivation for technological collaborations (Hagedoorn, 1993). Again this is not to say that developing new knowledge is the only rationale for technological alliances. Namely, inter-firm collaborations may simply serve the purpose of obtaining access to a proprietary technology (e.g., through licensing) or to the services of partners' specialized assets (e.g., production capacity, brand, distribution channels, market knowledge) that increase the value of a firm's proprietary technology. This leads to more extensive individual exploitation of firms' resources and capabilities (Hamel, 1991; Nakamura, Shaver, and Yeung, 1996). In these situations very limited learning is involved. What is important to emphasize here is that the likelihood of an alliance leading to mutual learning is greater in technological alliances than in non-technological ones.

Let us now focus attention on technological learning-oriented alliances. In accordance with the definition given above, inter-organizational learning requires transfer and integration of partners' capabilities—a difficult task, especially if the underlying knowledge is tacit, organizationally embedded, and subject to 'causal ambiguity' (Reed and DeFillippi, 1990; Simonin, 1999). In order to deal with such difficulties, the need arises for adequate control mechanisms that closely replicate those typical of hierarchical organizations and assure coordination of interdependent tasks (Kogut, 1988; Ring and van de Ven, 1992; Gulati and Singh, 1998). These include clear definition of authority relations, allocation of formal responsibility for decision-making, and creation of standardized procedures and rules. They also include less formal controls such as regular meetings between the personnel involved in the

[1] This latter notion of learning is popular in the 'learning race' literature, which stresses the competitive aspect arising from the wish of a firm to 'outlearn' its partner (Hamel, 1991). Nevertheless, inter-firm transfers of capabilities through alliances may occur independently of the presence of a competitive aspect. Note also that in the literature there are other interpretations of learning in alliances. Studies concerned with organizational learning emphasize that firms learn from the success and failures of their previous alliances and apply to subsequent collaborations lessons on how to design and manage such initiatives (see, for instance, Simonin, 1997). In addition, through the establishment of an alliance partners may obtain further information, thus learning about the prospects for success of a particular project (Mody, 1993). In this paper, we neglect these latter two interpretations of learning in alliances.

collaborative venture, the set-up of joint teams and task forces, and the transfer of managerial and technical personnel for extended periods of time, with the aim of assuring close interaction, continuing mutual adjustments, and the development of a common communication code (Inkpen and Dinur, 1998; Dyer and Singh, 1998; Gulati and Singh, 1998). Building such control mechanisms requires substantial relation-specific investments from partner firms especially in human capital, whose value largely vanishes if the venture fails (Dyer and Singh, 1998; Madhok, 2000; Oxley, 1999b). It also involves partially irreversible modifications of partner firms' own organization (e.g., closure of some units, reassignment of responsibility for some activities, redefinition of authority relations and communication flows). In turn, the large amount of relation-specific investments will lead firms to choose an equity form as a safeguard against partners' opportunistic behavior.[2]

A crucial problem with the competence perspective is that it has the same prediction as TCE as to the form of technological alliances. This makes it difficult to distinguish empirically between them. Therefore, taking into account the effect on alliance form of the similarity of partners' technological capabilities provides a valuable contribution to the literature. In fact the alleged coordination advantage of equity forms does depend on how difficult it is to transfer and integrate partners' knowledge. In this perspective, the similarity of firms' knowledge base acts as a moderating factor, influencing alliance form. If partners have developed competencies in different technological fields, mutual learning—whether it consists in the internalization of partners' capabilities or the co-development of new capabilities through knowledge pooling, will be difficult due to lack of absorptive capacity (Cohen and Levinthal, 1990). Under such circumstances the need arises for robust mechanisms to support interaction: as such mechanisms involve substantial relation-specific investments, firms are more likely to resort to equity governance modes. On the contrary, if firms have an overlapping knowledge base, their capacity to understand and absorb partners' knowledge is definitely greater: so mutual learning will be easier (Dyer and Singh, 1998). In addition, (bilateral) contractual collaborations may mimic some of the hierarchical controls of equity modes that favor inter-organizational learning. Actually, in numerous non-equity alliances an independent managerial hierarchy is appointed with the mandate of supervising and controlling joint activities and there often are exchanges of personnel and meetings attended by partners' representatives. Even though such coordination mechanisms are not as efficient as those embodied into equity forms,[3] they may be enough to support learning processes between partners that are equipped with sufficient absorptive capacity, whereas in this situation the higher set-up and administrative costs of equity forms may not be justified. Partners are then more likely to opt for a (bilateral) contractual collaboration.[4]

[2] For an analysis of the control mechanisms provided by hierarchical organizations see Conner and Prahalad (1996: 484), Ghoshal and Moran (1996: 33–36), Grant (1996: 114), and Kogut and Zander (1992, 1996). The above reasoning highlights the complementarity between the competence and the TCE perspectives (see Oxley, 1999b; Williamson, 1999). Note, however, that according to some proponents of the competence-based approach the alleged coordination advantage of hierarchical forms does not rely on the assumption of opportunism. For instance, Kogut and Zander (1996: 503) note that 'firms provide a sense of community by which discourse, coordination, and learning are structured by identity ... Through membership in a social community called the firm, identity is developed that changes the character and quality of human discourse and behavior.' See also Kogut and Zander (1992) and Conner and Prahalad (1996). However, if one also takes partner's opportunism into account, the competence-based reasoning is considerably reinforced.

[3] Contractual arrangements lack the safeguard against opportunism provided by shared ownership. In addition, they are generally project-based and have a shorter expected time horizon than equity modes. Consequently, there are fewer incentives for the parties to effect relation-specific investments aimed at supporting transfer and integration of knowledge. Accordingly, the allocation of decision power is far less formalized than with an equity joint venture, the definition of operating procedures and behavioral routines is less developed, and control mechanisms relying on ongoing mutual adjustments are used on a smaller scale and a less regular basis.

[4] Following Nooteboom (1992, 1999), mutual learning is most beneficial when the knowledge distance between partners is sufficiently large to favor novelty, but also sufficiently small to assure mutual understanding. Thus it might be argued that if the knowledge overlap between partners is really high there is no benefit in forming a learning-oriented alliance, as there is little to learn from each other. On the contrary, if it is minimal, the gain from mutual learning might not be worth the large coordination costs. Therefore, in such extreme situations alliances are more likely driven by other considerations than learning. Note, however, that the competence-based argument relating to the effects on alliance form of partners' technological specialization is conditional on the alliance being motivated by inter-organizational learning, an event that cannot be entirely ruled out even in such unfavorable conditions. For instance, investments in mutual understanding may allow to cross even a large cognitive distance between

The argument that in choosing the form of technological alliances the overlap of firms' knowledge base matters is indirectly confirmed by previous empirical studies. Mowery *et al*. (1996) analyze the convergence or divergence of partners' capabilities after the establishment of an alliance. They show that in alliances that exhibit convergence, thus signaling inter-firm transfer and integration of knowledge, the extent of the convergence is greater with an equity joint venture than with a contractual collaboration, and greater with a bilateral contractual collaboration than with a unilateral one. In addition, they find that experience in related technological areas positively influences the absorption of partners' capabilities. Simonin (1999) shows that whereas lack of expertise in the underlying technological fields of an alliance increases causal ambiguity thus hindering effective knowledge transfer between partners, such an effect largely vanishes if partners deploy substantial resources to support learning processes. This means that partners' absorptive capacity substitutes for commitment of physical and personnel resources dedicated to facilitating inter-organizational knowledge transfer. Hence if partners have sufficient absorptive capacity, the safeguard mechanisms inherent in equity forms are undeserved. Findings illustrated in Cantwell and Colombo (2000) lend support to such view. They show that the likelihood of two firms establishing a technological alliance generally increases with the similarity of their technological capabilities (see also Mowery, Oxley, and Silverman, 1998). However, when attention is confined to equity joint ventures, the opposite holds true, indicating that such form is especially suitable to combining partners' dissimilar technological capabilities.

On the contrary, the predictions of TCE as regards the effects on alliance form of the overlap of partner firms' knowledge base are ambiguous, as opposing forces allegedly are at work. As was said earlier, if firms have similar technological capabilities, they can easily understand and absorb each other's knowledge. On the one hand, under such circumstances it will be difficult for them to prevent unintended leakage of knowledge to alliance partners. *Ceteris paribus*, the need to cope with greater appropriability hazards makes use of equity forms more likely. On the other hand, the ability of firms to specify inputs, outputs, and actions to be taken under various contingencies is greater, making contracts less incomplete. Monitoring partners' behavior also is easier. As there is less room for opportunism, contractual hazards and the associated 'hold-up' problems are reduced. With all else equal, this favors use of non-equity forms.

The arguments of TCE and the competence perspective relating to the effects on alliance form of partners' technological specialization are synthesized in Figure 1. From the competence-based approach we thus derive the following hypothesis:

Hypothesis 1: With all else equal, in technological learning-oriented alliances greater divergence in partners' technological specialization will result in a higher propensity for equity modes.

partners (Nooteboom, 2004). Provided that a learning-oriented alliance is established, it is contended here that the amount of relation-specific investments required to support mutual learning will increase with the divergence of partners' knowledge base and so will the likelihood of partners resorting to an equity form. I am indebted to Bart Nooteboom for a clarifying discussion of this aspect.

		TCE		**Competence perspective**
		Transaction costs arising from contractual hazards	*Transaction costs arising from appropriability hazards*	*Coordination costs*
Partners' technological specialization	*Similar*	LOW	HIGH	LOW
	Different	HIGH	LOW	HIGH
The divergence of partners' technological specialization favors use of:		Equity forms	Non-equity forms	Equity forms

Figure 1. Effects on the form of technological alliances of partners' technological specialization

The above reasoning requires an important qualification. Real option theory (Dixit and Pindyck, 1994) argues that there is an opportunity cost of making an irreversible investment expenditure due to the lost option value of waiting for new information to arrive. Such cost increases with the uncertainty of the future returns the investment will generate. Therefore, when there is considerable uncertainty in the business environment firms may refrain from relation-specific investments so as to avoid the risk of incurring sunk costs if unpredicted contingencies occur (Pindyck, 1988, 1993). Such a line of reasoning has important implications for the form of alliances. Technological alliances are inherently more uncertain than production and commercial alliances, especially when they are aimed at mutual learning and the exploration of new technological fields. Under such circumstances partner firms may be induced to limit the amount of relation-specific investments, thus preserving flexibility and ease of adjustment.[5] Hence, in contrast with the predictions of both TCE and the competence perspective, the balance may shift against use of equity modes for technological alliances, in favor of bilateral contractual modes which in a sense optimize the trade-off between flexibility and commitment.[6] We therefore derive the following hypothesis:

Hypothesis 2: With all else equal, in technological alliances bilateral contractual modes will be relatively more frequent than both equity joint ventures and unilateral contractual modes.

THE DATA AND THE SPECIFICATION OF THE ECONOMETRIC MODELS

The data

The data on alliances used in this paper are provided by the ARPA database developed at Politecnico di Milano. ARPA surveyed agreements in information technology (IT) industries (i.e., semiconductor, data processing, and telecommunications) between 1980 and 1986. IT industries account for a substantial share of the total number of agreements established by firms and the rate of formation of new alliances peaked in the mid 1980s (see Hagedoorn and Schakenraad, 1992). In addition, the early 1980s were marked by high technological turbulence in such industries; there were sustained technical changes due to the introduction of major innovations such as the IBM PC in late 1981, and aggressive technological competition both between incompatible platforms within a particular segment (e.g., DOS, CP/M and Apple platforms in the microcomputer segment) and across different industry segments (e.g., between microcomputers and minicomputers, between supermini and mainframes).[7] Accordingly, the development of new capabilities was a key strategic priority for firms. Therefore, the sample of alliances considered in this study offers an ideal testbed of arguments from different theoretical streams as to the determinants of the form of strategic alliances in a high-tech dynamic environment.

Information contained in ARPA was gathered from the international financial press, technical magazines, and specialist studies. ARPA adopts a standardized classification of agreements similar to the one of the CATI database (see Hagedoorn, 1993); it considers the year of establishment of the collaboration, the organizational form, and the nature of the involved activities. As to this latter aspect, a distinction is made between (a) technological activities, including research, development, design, engineering, and knowledge transfer, (b) production, and (c) commercial activities, that is, marketing, sales, distribution, and after-sale services. Of course, alliances may combine different activities (e.g., technology and production). The identity of the partners of each alliance, and the group to which they eventually belong, is also known. Unfortunately, ARPA does not provide reliable information on the underlying logic of the partnerships, a well-known shortcoming of use of secondary sources (see Glaister and Buckley, 1996).

[5] The fact that the possibility of technological obsolescence deters specialized investments, thus diminishing the incentives to use hierarchical governance modes, has long been recognized in the management literature (see Balakrishna and Wernerfelt, 1986). On the relation between environment uncertainty and alliance form, see also Harrigan (1988: 146).

[6] The fact that the establishment of an equity joint venture entails in its own greater unrecoverable commitments than a contractual relation reinforces this argument. For a discussion of the trade-off between flexibility and commitment in structuring alliances see, for instance, Chi and McGuire (1996), Folta (1998), and Chi (2000).

[7] On technological competition in IT industries in the period under study and its implications for industry dynamics see, for instance, Langlois and Robertson (1992) and Bresnahan and Greenstein (1999).

ARPA covers a total of 2014 cooperative agreements; they involve 1574 partners belonging to 1177 independent entities (see Cainarca, Colombo, and Mariotti, 1992). In this work, I focus on 67 firms from the world's largest IT companies. Selection of the firms was based on two criteria. First, data were needed on firm-specific characteristics (e.g. size, R&D expenses) over the entire period under consideration. Such data were obtained from various sources: specialized magazines such as *Datamation* and *Electronic Business*, sector studies (*Benn Electronic File Directory* and *Gartner Group Top 100 Almanac*), firms' annual reports and other directories (such as the *Japan Company Handbook*). Considerable effort was devoted to checking the coherence of the various sources. Availability of such data restricted the sample to 100 firms (see Colombo, 1995). Second, I obtained access to the data set at the University of Reading on the patent activity in the United States of the world's largest firms during the period 1969–95. The Reading data set includes information on 784 firms which account for over 46 percent of all patents granted in the United States between 1969 and 1995. Each patent is assigned to one of 56 technological sectors according to the type of technological activity with which it is primarily associated. Of the 100 above-mentioned firms, 67 were included in the Reading database. The final sample is composed of 34 North American, 20 European and 13 Japanese enterprises and can be regarded as representative of the world's largest firms in IT industries. In the author's view, coverage of all areas of the 'triad' represents a significant improvement with respect to previous empirical studies on this issue.

Following recent studies on the form of strategic alliances (Garcia Canal, 1996; Mowery *et al.*, 1996; Oxley, 1997, 1999a; Cantwell and Colombo, 2000), I consider equity joint ventures, non-equity bilateral collaborations and non-equity unilateral (i.e., quasi-market) agreements. The 'non-equity bilateral agreement' category comprises joint R&D agreements, technology-sharing agreements, cross-licenses, arrangements aimed at sharing production facilities, logistics resources and/or distribution networks, and co-marketing agreements. All such arrangements involve joint performance of activities, sharing, and/or exchange of resources among partners. In order to manage interdependencies, they generally incorporate control mechanisms such as the creation of a dedicated managerial hierarchy, joint work teams, and transfer of technical and managerial personnel, that simulate to some extent the characteristics of equity forms. With respect to these latter forms, they enjoy a flexibility advantage related to the smaller amount of relation-specific investments and associated sunk costs (which, however, are greater than with unilateral contractual forms, see below). The 'non-equity unilateral agreement' category includes R&D contracts, technology transfer agreements, licenses, customer–supplier relations, franchising agreements, and other unilateral commercial agreements (e.g., value-added retailer, original equipment manufacture). These agreements generally rely on the division of labor and the specialization of tasks among partners; each partner is in charge of a specific activity and transfers the output to the other parties. The extent of the interaction between partners is low. Accordingly, the above-mentioned coordination mechanisms generally are absent, relation-specific investments by partners are minimal, and there is no mutual exchange of hostages in kind. The risk of sunk costs also is minimal.

For reasons that will be explained later, I confine attention to alliances concluded between 1983 and 1986. In the period 1983–86 ARPA surveyed 278 alliances between the sample firms. Non-equity unilateral arrangements, non-equity bilateral collaborations, equity joint ventures, and acquisitions of a minority interest accounted for 45.4 percent (about half of which are licenses), 32.7 percent, 19.4 percent, and 2.5 percent, respectively. Due to a 'small numbers' problem, minority acquisitions were excluded from the empirical analysis.

Specification of the econometric models

The empirical analysis is based on the estimates of discrete choice models. In order to determine what factors influence the relative probability that a collaboration is an equity joint venture (EJV) or a contractual (i.e., non-equity) collaboration, I resort to a binomial logit model. The dependent variable equals one for equity joint ventures. I also estimate a multinomial logit model (see Greene, 1991) that distinguishes between three categories of alliances: equity joint ventures, non-equity bilateral forms (NEB), and non-equity unilateral forms (NEU). With no loss of generality, in this latter model the NEB category is taken as the baseline of the econometric estimates.

The explanatory variables of the model are illustrated in what follows (see Table 1).

Firms' overlap of knowledge base

In view of the objectives of the present paper, developing a reliable indicator of the similarity of the technological capabilities of the partners of an alliance is of crucial importance. In recent empirical work (see, for instance, Jaffe, 1989; Mowery *et al.*, 1996, 1998) firms' technological resources have been measured through patent data. Such an approach relies on the assumption that in spite of the fact that patents represent only codified knowledge, they indicate the technological areas in which firms are active. In other words, codified knowledge and tacit knowledge are assumed to be complements rather than substitutes. In this paper I follow this tradition and use SIMILAR CAPABILITIES as an indicator of the overlap of firms' knowledge base. Such a variable is defined as follows (see Cantwell and Barrera,

Table 1. The explanatory variables of alliance form

Variable	Definition
SIMILAR CAPABILITIES	Average value of the correlation indices between the distributions of the revealed technological advantages[a] of any pair-wise combination of the partners of an alliance across 31 technological fields related to information technologies
TECH	Dummy variable: it equals 1 for alliances that involve R&D and/or design and/or engineering and/or technology transfer; otherwise it equals 0
MIXED	Dummy variable: it equals 1 for alliances that involve several functional activities (technological, productive, and/or commercial activities)
NPARTNERS	Number of partners of an alliance
NGEOAREAS	Number of geographical areas (i.e., North America, Europe, Japan) from which the partners of an alliance originate
PREVIOUS TIES	Ratio between the number of prior alliances that link the partners of an alliance to each other and were established in the previous 3 years and the maximum number of individual linkages between them[b]
SAME PRIMARY SECTOR	Dummy variable: it equals 1 if all partners of an alliance have the same primary sector of activity in information technologies; otherwise it equals 0
SECTOR IN COMMON	Dummy variable: it equals 1 if (a) all partners of an alliance are in one or more common sectors in information technologies and (b) this is not their primary sector of activity; otherwise it equals 0
DATE	Year in which an alliance was established
ALLIANCE EXPERIENCE	Average number of previous alliances established by the partners of a collaboration
SIZE	Average value of total sales of the partners of an alliance in the year in which the alliance was established (billion US dollars, 1980 prices)
R&D INTENSITY	Average value of the R&D-to-sales ratio of the partners of an alliance in the year in which the alliance was established
SIZEGAP	Ratio between the value of total sales of the smallest firm and that of the largest firm in an alliance in the year in which the alliance was established
R&DDIFF	Largest difference between the R&D-to-sales ratio of the partners of an alliance in the year in which the alliance was established

[a] The revealed technological advantage (RTA_{ij}) of firm i in technological class j is calculated as follows. Let P_{ij} be the number of U.S. patents granted to firm i in technological class j over the period 1969–95. Then $RTA_{ij} = (P_{ij}/\Sigma_j P_{ij})/(\Sigma_i P_{ij}/\Sigma_{ij} P_{ij})$, $i = 1, \ldots, 67$; $j = 1, \ldots, 31$.
[b] The maximum number of individual linkages between the partners of an alliance equals $N(N-1)/2$, with N being the number of partners.

1998; Cantwell and Colombo, 2000). Let RTA_{ij} be the revealed technological advantage of firm i in technological field j. Denoting by P_{ij} the number of U.S. patents granted to firm i in technological field j over the period 1969–95, RTA_{ij} is given by the following expression: $RTA_{ij} = (P_{ij}/\Sigma_j P_{ij})/(\Sigma_i P_{ij}/\Sigma_{ij} P_{ij})$. Only 31 technological fields associated with IT sectors are considered. In other words, RTA_{ij} coincides with the ratio of the share accounted for by a given technological class out of the number of U.S. patents in IT granted to the firm under consideration, to the share of the same technological class out of the total number of U.S. patents in IT granted to all sample firms. RTA_{ij} varies around one, with values greater than one suggesting that a firm is comparatively specialized in the activity in question. Pearson's correlation coefficient r_{ik} is then calculated between the RTA distributions of any pair-wise combination of firms i and k across the 31 technological fields. Such an index measures the (positive or negative) correlation between the patterns of technological specialization of firms, as are reflected in the RTA values. If tacit and codified knowledge are complements, the distribution of a firm's patents across technological fields quite accurately reflects the underlying distribution of technological capabilities. Thus the index is a proxy of the extent of overlapping of partners' knowledge base. The value of SIMILAR CAPABILITIES for a given alliance is given by the average value of r_{ik} calculated across all pairs of firms i and k involved in the alliance. Therefore, the more technologically related are partner firms, the more similar will be the distributions of their patents, and the greater will be the value of SIMILAR CAPABILITIES.[8]

SIMILAR CAPABILITIES reflects the capacity of alliance partners to absorb each other's knowledge. If partners specialize in different technological fields, and thus such a variable takes a negative value, learning from each other within a technological alliance will be difficult. Under such circumstances equity joint ventures will be relatively more efficient than contractual modes due to the need for better coordination and more robust communication channels between partners. Similarly, the larger the (positive) value of SIMILAR CAPABILITIES, the more likely that firms will resort to less expensive contractual alternatives. On the contrary, I expect SIMILAR CAPABILITIES not to exhibit any discriminating power for alliances that concentrate on production and commercial activities (i.e., when TECH equals 0, see below).[9]

Of course, the above predictions implicitly rely on the assumption that inter-organizational learning plays a key role in technological alliances, while it does not in alliances focused on production and commercial activities. As was mentioned earlier, such an assumption is comfortably supported by the available empirical evidence on the motives for alliances. Nonetheless, it is fair to recognize that even alliances with a technological component may serve purposes other than learning; for instance, they may be aimed at accessing the specialized R&D services provided by partners, setting a new standard, or reducing technological competition. Unfortunately, I do not have any precise information on the motives of the alliances included in the sample. Nonetheless should a technological alliance not involve mutual learning, SIMILAR CAPABILITIES would lose its explanatory power of alliance form. Thus failure to distinguish learning-oriented from other technological alliances biases the estimated coefficient of such a

[8] The measure used here is conceptually very close to Jaffe's (1989) indicator of technological proximity. The main advantage is that use of RTA values allows to control for the fact that firms' propensity to patent varies systematically across technologies. Mowery *et al*. (1996, 1998) use the cross-citation rate (i.e., the share of citations to firm j's patents in firm i's patents out of the total number of citations in firm i's patents) as a measure of technological overlap. We believe that, for our purposes, an index based on count of patents is more informative, as it more directly reflects the technological capabilities of firms. For a discussion of limitations inherent in the use of patent citations, see Jaffe, Trajtenberg, and Henderson (1993). The main drawback of a measure based on patent count is that, in order for it to be reliable, it must be based on a sufficiently large number of patents. Thus its use is confined to firms with substantial patenting activity observed over a sufficiently long period of time.

[9] As SIMILAR CAPABILITIES is calculated over the period 1969–95, endogeneity problems may arise. In other words, the choice of the governance mode of alliances may influence the subsequent evolution of firms' capabilities. The decision not to base the calculation of SIMILAR CAPABILITIES on the 1969–82 period was mainly determined by the desire to avoid problems due to 'small numbers.' Note, however, that a preliminary investigation showed that the patterns of technological specialization of sample firms are quite stable over time (on this topic see also Patel and Pavitt, 1997). In addition, the findings of previous studies on the impact of the governance mode of alliances upon firms' technological capabilities provide mixed evidence (Nakamura *et al*., 1996; Mowery *et al*., 1996). Lastly, should the choice of an equity form result in greater similarity between partners' technological specialization due to more profitable interaction, as is argued by the aforementioned literature, the results of the present paper would be reinforced.

variable towards null.[10] Hence, the findings that are illustrated in the following section relating to the impact of partners' technological specialization on the form of technological alliances are to be considered as conservative.

Other explanatory variables

In accordance with previous literature, other explanatory variables were considered.

The TECH dummy equals 1 if a collaboration involves a technological component (i.e., R&D, design, engineering, and/or knowledge transfer) and 0 if it concentrates on production and/or commercial activities. Both TCE and competence-based theories predict a positive effect of such a variable on the probability of resorting to organizational forms that incorporate more effective hierarchical controls, on the grounds of transaction costs and learning considerations, respectively. Therefore, EJV should be the most suitable form for a technological alliance, and NEU the least suitable one. However, as is indicated by real option theory, when there is high uncertainty aversion towards commitment of unrecoverable investments may lead firms to choose a less hierarchical form, with opposite implications as to the sign of the coefficient of TECH.

Furthermore, complexity of alliances is captured by a number of variables: the number of partners (NPARTNERS), the geographic scope measured by the number of geographical areas (i.e., North America, Europe, and Japan) to which partners belong (NGEOAREAS), and a dummy variable (MIXED) that distinguishes alliances that span over several activities (e.g., technology *and* production) from less complex alliances. The coefficients of such variables should be positive in the EJV estimates (and possibly negative in the NEU estimates of the multinomial specification) due to the need for more hierarchical forms to govern complex transactions. In order to ensure easier comparability with previous works, I also introduced into the models the interactive term TECH $\times$ MIXED. Thus the effects of technological factors on alliance form are allowed to differ according to the complexity of the activities involved in the alliance.

In addition, I considered the effect of the establishment of previous alliances between partner firms upon the form of subsequent alliances, with prior ties being indicative of the presence of trust. PREVIOUS TIES is defined as the ratio between the number of prior alliances between the partners of a given collaboration that were concluded in the previous 3 years and the maximum possible number of linkages between them if one neglects repeated ties; this number equals 1 if there are only two alliance partners and increases with the number N of partners as $N(N-1)/2$.[11] Gulati (1995) and Gulati and Singh (1998) find that the likelihood of choosing an equity form as opposed to a contractual form decreases with the number of prior alliances established by partners with each other; this is interpreted as evidence that trust substitutes for use of equity modes. Nevertheless, this result is not confirmed by other studies (see Garcia Canal, 1996; Oxley, 1997, 1999a). Thus the predicted sign of PREVIOUS TIES is uncertain.

In accordance with previous work, some additional control variables were introduced into the models. SAME PRIMARY SECTOR is set to 1 when all partners in a given alliance have the same primary sector of activity (either semiconductor or data processing or telecommunications). SECTOR IN COMMON equals 1 if all partners are in one or more common sectors, except if the common sector coincides with their primary sector of activity (in this case, SAME PRIMARY SECTOR = 1 and SECTOR IN COMMON = 0). Tao and Wu (1997) suggest that when partners compete in the same downstream business, cooperative activities should be conducted in an equity joint venture so as to effectively deal with leakage of knowledge; if partners are in different industries, the governance mode makes no difference. This view implies a positive sign for the above-mentioned variables in the EJV estimates. ALLIANCE EXPERIENCE indicates the average number of previous agreements established by the partners of an alliance with both firms that are included in the sample and firms that are

[10] Technological alliances are most likely driven by motives other than mutual learning when SIMILAR CAPABILITIES takes extreme values (see footnote 4). This reinforces the above argument.

[11] As data on alliances are available from 1980, this is the reason why in this study attention is confined to the form of alliances that were established after 1982. An additional dummy variable was also calculated, which is set to 1 if all partners of the alliance under scrutiny were involved in one or more collaborations between each other in the previous 3 years. The estimates obtained when such a variable replaces PREVIOUS TIES do not substantially differ from those that will be presented here. They are available from the author on request.

Table 2. Descriptive statistics and correlation matrix of the explanatory variables

	Mean	S.D.	Min.	Max.	SIMILAR CAPABILITIES	TECH	MIXED	NPARTNERS	NGEOAREAS	PREVIOUS TIES
SIMILAR CAPABILITIES	−0.002	0.272	−0.583	0.916	1.00					
TECH	0.472	0.500	0	1	0.10	1.00				
MIXED	0.494	0.501	0	1	−0.03	0.04	1.00			
NPARTNERS	2.199	0.885	2	11	0.10	0.21	−0.05	1.00		
NGEOAREAS	1.649	0.478	1	2	−0.12	−0.23	0.01	−0.22	1.00	
PREVIOUS TIES	1.074	1.258	0	5	−0.01	0.07	0.12	0.07	0.15	1.00
SAME PRIMARY SECTOR	0.373	0.484	0	1	−0.06	−0.01	−0.07	−0.05	−0.06	−0.03
SECTOR IN COMMON	0.782	0.413	0	1	−0.03	−0.11	0.09	−0.06	0.08	0.08
DATE	84.697	1.101	83	86	0.06	0.04	−0.05	−0.07	0.07	0.09
ALLIANCE EXPERIENCE	28.209	15.942	2	89	0.14	−0.02	−0.17	−0.05	0.11	0.27
SIZE (bl. U.S. $ at 1980 prices)	7.301	7.138	0.905	33.177	0.13	−0.09	−0.18	−0.06	−0.02	0.09
R&D INTENSITY	0.077	0.021	0.026	0.130	0.05	0.13	−0.07	−0.03	−0.10	0.11
SIZEGAP	0.411	0.290	0.005	0.986	−0.17	0.04	0.08	−0.13	0.11	−0.04
R&DDIFF	0.037	0.030	0.001	0.127	−0.02	−0.01	0.00	0.11	−0.08	−0.14

	SAME PRIMARY SECTOR	SECTOR IN COMMON	DATE	ALLIANCE EXPERIENCE	SIZE	R&D INTENSITY	SIZEGAP	R&DDIFF
SAME PRIMARY SECTOR	1.00							
SECTOR IN COMMON	−0.50	1.00						
DATE	0.02	−0.03	1.00					
ALLIANCE EXPERIENCE	−0.04	0.02	0.62	1.00				
SIZE (bl. U.S. $ at 1980 prices)	0.02	−0.06	−0.05	0.46	1.00			
R&D INTENSITY	−0.11	0.20	0.10	0.04	−0.23	1.00		
SIZEGAP	−0.16	0.23	0.04	−0.08	−0.49	0.14	1.00	
R&DDIFF	−0.15	0.14	−0.18	−0.11	0.00	0.36	0.03	1.00

not; it takes into account the influence possibly exerted by experience in managing alliances upon the organizational form of subsequent alliances. DATE indicates the year in which an alliance was established; it controls for time-specific patterns. This latter variable is positively correlated with ALLIANCE EXPERIENCE (the correlation index equals 0.62, see Table 2): this leads to collinearity problems. However, I share Oxley's (1997) view that ALLIANCE EXPERIENCE nicely reflects the growth of the alliance-related experience of the sample firms over the 1980s. This is why both variables are present in the models. I also considered the average sales (SIZE) and R&D to sales ratio (R&D INTENSITY) of the partners of a collaboration, measured in the year in which the collaboration was established. Lastly, I introduced into the models the ratio between total sales of the smallest and largest firms in an alliance (SIZEGAP) and the largest difference between R&D intensities (R&DDIFF). On the one hand, size and R&D intensity have been shown by previous empirical work to influence firms' propensity to form strategic alliances (see Colombo, 1995; Sakakibara, 2002). In addition, it has previously been argued that such firm-specific characteristics may have an impact on the governance of transactions, even though empirical evidence in support of such a claim is rather weak (see, for instance, Mowery *et al.*, 1996). On the other hand, differences in size and R&D intensity between firms have sometimes been used as proxies of the extent of divergence of firms' capabilities (Nakamura *et al.*, 1996). Accordingly, they are included among the independent variables in order to control for the effects of a capability gap which might not be adequately captured by the SIMILAR CAPABILITIES variable.

All independent variables are listed in Table 1. Table 2 exhibits descriptive statistics and the correlation matrix. With few exceptions, the correlation between the explanatory variables is rather low.

EMPIRICAL FINDINGS

Results of the econometric estimates of the binomial and multinomial logit models (Models I and II, respectively) are illustrated in Table 3. The table shows the estimated values of the coefficients of the independent variables, their standard errors, and individual and joint significance levels. The results of Wald χ^2 tests of the hypothesis relating to the effects on the form of technological alliances of the SIMILAR CAPABILITIES variable are also illustrated at the bottom of the table.

The main objective of this study was to highlight the role played by the similarity of partners' technological specialization in influencing the choice of the form of technological alliances. The findings of the regressions clearly support the argument inspired by the competence perspective that the likelihood of choosing an equity mode for a technological agreement increases with the diversity of the technological capabilities of partners (Hypothesis 1). When TECH equals 1, SIMILAR CAPABILITIES has a negative coefficient in both Model I (i.e., $a_1 + a_3$) and the EJV column of Model II (i.e., $a_1^{\mathrm{EJV}} + a_3^{\mathrm{EJV}}$). The null hypothesis that such a variable has no significant effect (i.e., H_0: $a_1 + a_3 = 0$ and $a_1^{\mathrm{EJV}} + a_3^{\mathrm{EJV}} = 0$) is rejected by a Wald χ^2 test at 95 percent and 90 percent confidence levels respectively (the χ^2 values equal 4.1 and 3.5). On the contrary, when TECH equals null SIMILAR CAPABILITIES exhibits no statistical significance. Quite unsurprisingly, partners' technological competencies seem not to affect the organizational form of alliances that do not have a technological component.

Let us now consider the impact on organizational form of the nature of the activities included in an alliance. In particular, I want to check whether technological alliances are more frequently governed through equity modes than other (i.e., non-technological) alliances. In this regard, Model I offers no clear indication. The coefficient of TECH is insignificant; furthermore, with MIXED equal to 1 the null hypothesis that having a technological component does not influence alliance form (i.e., H_0: $a_2 + a_5 = 0$) cannot be rejected by a Wald χ^2 test at conventional confidence levels ($\chi^2 = 1.0$). On the contrary, the evidence provided by Model II is rather interesting. First of all, it clearly highlights that unilateral contractual arrangements are unsuitable to technological alliances. In fact, in the NEU column, the negative coefficient of TECH is significant at 99 percent; the value of the Wald χ^2 test relating to the (negative) sum of the coefficients of TECH and the interactive term TECH $\times$ MIXED again is significant at 99 percent ($\chi^2 = 19.9$). As to the EJV estimates, the coefficient of TECH is negative though insignificant, while the sum of the coefficients of TECH and TECH $\times$ MIXED is negative and significant at 99 percent (the Wald χ^2 test equals 13.8). To sum up, in accordance with Hypothesis 2 when an alliance has a technological component, the likelihood of the alliance having a bilateral contractual form increases to the detriment of both equity forms and non-equity unilateral forms.

In order to illustrate more clearly the above results, a simulation study based on the estimates of the multinomial logit model (i.e., Model II) was carried out. This is an especially useful exercise with such models, as marginal effects need not have the same sign as the estimated coefficients. More precisely, a 'benchmark' alliance was first

Table 3. Estimates of binomial and multinomial logit models

		Model I	Model II	
		EJV	EJV	NEU
a_0	Constant	−38.186	−15.114	31.669
		(23.211)	(29.650)	(24.779)
a_1	SIMILAR CAPABILITIES	−0.873	0.893	1.895
		(1.017)	(2.264)	(1.996)
a_2	TECH	0.568	−1.150	−2.505***
		(0.982)	(1.313)	(0.624)
a_3	TECH × SIMILAR CAPABILITIES	−1.915	−4.458	−3.231
		(1.705)	(2.960)	(2.343)
a_4	MIXED	3.171***	4.705***	1.688*
		(0.799)	(1.462)	(0.983)
a_5	TECH × MIXED	−1.033	−2.519	−2.011*
		(1.033)	(1.587)	(1.181)
a_6	NPARTNERS	0.896***	0.933***	−0.498
		(0.267)	(0.276)	(0.578)
a_7	NGEOAREAS	0.372	1.215**	1.501***
		(0.446)	(0.532)	(0.458)
a_8	PREVIOUS TIES	0.445***	0.473**	−0.016
		(0.172)	(0.216)	(0.212)
a_9	ALLIANCE EXPERIENCE	−0.022	0.005	0.041
		(0.025)	(0.033)	(0.024)
a_{10}	DATE	0.403	0.127	−0.385
		(0.275)	(0.354)	(0.297)
a_{11}	SAME PRIMARY SECTOR	−0.028	0.136	0.308
		(0.491)	(0.731)	(0.569)
a_{12}	SECTOR IN COMMON	−0.587	−0.958**	−0.175
		(0.611)	(0.882)	(0.630)
a_{13}	SIZE	0.044	0.068	0.017
		(0.045)	(0.063)	(0.043)
a_{14}	R&D INTENSITY	−34.619***	−34.147	−1.127
		(12.115)	(13.576)	(12.578)
a_{15}	SIZEGAP	1.640**	1.739	−0.036
		(0.778)	(1.005)*	(0.875)
a_{16}	R&DDIFF	−3.109	−1.597	−3.766
		(7.852)	(10.038)	(7.580)
	Log-likelihood	−92.61	−174.22	
	No. of observations	271	271	
	LR test (d.f.)	85.4 (16)***	212.1 (32)***	
	Wald χ^2 test (d.f.): $H_0: a_1 + a_3 = 0$	4.1 (1)**		
	Wald χ^2 test (d.f.): $H_0: a_1^{EJV} + a_3^{EJV} = 0$		3.5 (1)*	
	Wald χ^2 test (d.f.): $H_0: a_1^{NEU} + a_3^{NEU} = 0$		1.0 (1)	

* $p > 0.9$;
** $p > 0.95$;
*** $p > 0.99$
Standard errors or degrees of freedom between parentheses.
EJV, equity joint ventures; NEU, non-equity unilateral (i.e., quasi-market) arrangements.

defined in the following way. All dummy variables but TECH, MIXED, and SECTOR IN COMMON were set to 0, all discrete variables were evaluated at their median value, and all remaining (i.e., continuous) variables were evaluated at their mean value. In particular, the benchmark alliance has a technological component (TECH = 1) in addition to production and/or commercial components (MIXED = 1), and has been established by two partners located in different geographical regions. The probability that each of the three organizational forms under consideration (i.e., EJV, NEB and NEU) is chosen was then calculated (a) when all explanatory variables have their default value, and (b) when individual explanatory variables were assigned specific values, with all remaining variables being equal to the 'benchmarking' value. In particular, the following cases were considered. MIXED = 0 indicates an alliance that exclusively focuses on technological activities. TECH = 0 denotes a production and commercial alliance. Lastly, SIMILAR CAPABILITIES was assigned a 'low' and a 'high' value respectively. The results of the simulations are illustrated in Table 4.

Table 4. Simulation of the probability of an alliance having a specific organizational form

	EJV	NEB	NEU
BENCHMARK (TECH = 1, MIXED = 1)	22.0%	51.0%	26.9%
SIMILAR CAPABILITIES = LOW (−0.322)	42.7%	31.7%	25.6%
SIMILAR CAPABILITIES = HIGH (0.384)	7.6%	70.2%	22.1%
MIXED = 0	2.7%	56.3%	41.0%
TECH = 0	25.5%	1.5%	73.0%

EJV, equity joint ventures; NEB, non-equity bilateral agreements; NEU, non-equity unilateral (i.e., quasi-market) agreements.
Calculations are based on estimates of the multinomial logit model (Model II, see Table 3).
The '*BENCHMARK*' collaboration is defined as follows. All dummy variables are equal to 0 except TECH, MIXED, and SECTOR IN COMMON, which are equal to 1; all discrete variables are equal to their median value and all remaining (i.e., continuous) variables are equal to their mean value. As to SIMILAR CAPABILITIES, the probabilities associated with the different organizational forms have been computed in correspondence with the lowest value of the 1st decile and the highest value of the last decile (i.e., in correspondence with the 27th alliance in descending and ascending orders, respectively).

First of all, they highlight the large magnitude of the impact of SIMILAR CAPABILITIES on the choice of alliance form. When partners of a complex technological collaboration (i.e., TECH = 1, MIXED = 1) have a largely overlapping knowledge base so that SIMILAR CAPABILITIES takes a 'high' (positive) value, the probability associated with an equity joint venture is less than 8 percent, with all remaining variables being evaluated at their default value. When the partners are specialized in different technological fields, a situation which is denoted by a 'low' (and negative) value of this variable, this probability is about 43 percent. Second, let us consider an alliance that spans over several functional activities (MIXED = 1). If such an alliance does not have a technological component (TECH = 0) with all other variables at their default value, the estimated probability of the alliance having a bilateral contractual form is only 1.5 percent. However, if the alliance does have a technological component as in the 'benchmark' case, this probability increases to 51 percent. The values relating to non-equity unilateral forms and equity joint ventures decrease from 73 percent to 27 percent and from 25.5 percent to 22 percent, respectively.

As to the remaining explanatory variables, the estimates presented in Table 3 show that, in accordance with the evidence provided by previous studies inspired by TCE, firms are more likely to resort to equity modes the more complex is a collaboration. In both Model I and the EJV column of Model II NPARTNERS and MIXED have positive and statistically significant (at 99%) coefficients. The coefficient of NGEOAREAS also is positive, though insignificant in Model I; in Model II it is positive and significant in both the EJV and the NEU estimates (at 95% and 99%, respectively). Furthermore, the argument that trust arising from previously established alliances renders use of equity forms unnecessary in subsequent collaborations is not supported by our findings. PREVIOUS TIES has a positive and significant coefficient in both Model I and the EJV column of Model II (at 99% and 95%, respectively).

Lastly, let us consider control variables. With a few exceptions, their overall explanatory power is rather modest. First, there is no evidence that firms which are in the same sector of activity are more inclined towards equity joint ventures. The coefficients of both SAME PRIMARY SECTOR and SECTOR IN COMMON are always insignificant.

The same holds true for DATE and ALLIANCE EXPERIENCE. On the contrary, equity forms seem to be relatively more likely if firms have low R&D intensity and are of similar size. As to this latter result it is worth remembering that even the smallest firms in our sample are rather large; thus its validity cannot be extended to other firm size categories (e.g., alliances between large and small firms).

DISCUSSION

The main objective of this paper was to provide an empirical test of arguments suggested by the contractual and competence perspectives as regards the organizational form of technological alliances. On the one hand, TCE and other contractual theories of the firm highlight the need to cope with appropriability and other transaction hazards connected with firms' opportunism, and emphasize the transaction cost-economizing properties of equity forms. On the other hand, the competence perspective argues that the main motive for the establishment of technological alliances is the development of new capabilities through inter-organizational learning; therefore, the need to support learning processes allegedly is the key factor for the choice of governance mode of such alliances. In this regard, one of the major problems is that the predictions of such theories often coincide; in particular, both TCE and competence-based theories claim that equity forms are more suitable for governing technological alliances.

In order to disentangle the two perspectives empirically, special attention was given to the role played by the similarity of firms' knowledge base in influencing alliance form. It was shown that the likelihood of choosing an equity form for a technological alliance decreases with the proximity of firms' technological specialization. This is an interesting contribution to the debate on alliance form. Actually, TCE has no clear predictions as to the influence exerted by this factor on the choice of the governance mode of alliances. The divergence of partners' technological capabilities may lead to both a decrease or an increase of transaction costs, depending on whether appropriability hazards engendered by unintended knowledge spillovers to partners or contractual hazards associated with the 'hold-up' problem prevail. On the contrary, the competence-based approach argues that learning is easier if the partners of a technological alliance have developed expertise in the same technological fields, as they have greater capacity to absorb each other's knowledge. Under such circumstances, the need for coordination mechanisms that allow close interaction between the partners and facilitate coordination of the activities of the alliance but involve substantial relation-specific investments is considerably reduced, and so is the need for equity forms. In the industries under examination there are considerable appropriability hazards due to technological spillovers; the lower probability of equity forms when partners' technological specialization is similar is unlikely to be explained simply by a decrease of contractual hazards. Therefore, this result suggests that the extent of the coordination advantage of equity forms depends on the characteristics of the knowledge base of alliance partners, an argument which is peculiar to the competence perspective.

Previous studies have already provided evidence relevant to the relation between firms' capabilities and alliance form. Simonin (1999) shows that significant differences in knowledge base between alliance partners which usually impede learning may be overcome by commitment of substantial resources dedicated to knowledge transfer. Mowery *et al*. (1996) find that both use of equity forms and partners' overlapping knowledge base promote convergence of partners' capabilities. Mowery *et al*. (1998) and Cantwell and Colombo (2000) highlight that the heterogeneity of firms' capabilities affects the likelihood of establishing a technological alliance and that such an effect is contingent on alliance form. The findings of the present work are consistent with such 'stylized facts' and support in a more direct way the view that bringing the consideration of firms' idiosyncratic capabilities into the governance question, as is suggested by the competence-based literature, is a valuable complementary addition to more traditional arguments based on TCE and other contractual theories.

The empirical results presented in the previous section diverge from those of previous studies in two worthwhile respects.

First, in technological alliances bilateral contractual modes were found to be relatively more frequent than both unilateral contractual modes and equity joint ventures; this latter result contrasts with those of most previous works.[12] There are various possible explanations for this difference. First of all, it may partially be traced to industry biases. The characteristics of technology do differ across industries as to aspects such as the degree of tacitness and appropriability hazards (see, for instance, Levin *et al.*, 1987) which are expected to influence the relative appeal of different governance modes. Second, all firms analyzed in this study are established oligopolistic leaders. Such firms may have greater propensity to use non-equity arrangements than smaller firms. On the one hand, large firms are better able than small firms to protect their technological knowledge through means other than those provided by the governance structure of an alliance (e.g., retaliation). On the other hand, reputation effects that discourage opportunistic behavior may play a relatively more important role when a collaboration involves large oligopolistic firms.

Third, the empirical analysis focuses on three closely related IT industries. This has two implications for the issue at hand. From one side, I may have been able to cover sector-specific sources of information (especially technical magazines) to a larger extent than in cross-sectoral studies; consequently, a relatively greater number of minor technological alliances which may have gone unremarked in such studies is possibly included in my data set. From the other side, the results of the present work show that the likelihood of a technological alliance having an equity form increases with the divergence of the technological specialization of partners. Firms that operate in different industries likely have more different technological specializations than those that are in the same or in closely related industries. Thus failure of previous cross-sectoral studies to take into account the impact on the form of technological alliances of the proximity of the knowledge base of partners may also be partially responsible for differences in my results. In accordance with the above arguments, the share of the total number of agreements accounted for of equity joint ventures is less than 20 percent in my data set, while it was 28 percent, 29.4 percent, and 41 percent in Gulati and Singh (1998), Oxley (1999a), and Osborn and Baughn (1990), respectively.

Fourth, and more importantly, in the period under scrutiny major technological innovations associated with the introduction of the IBM PC occurred in IT industries. On the one hand, the need for established firms to develop new technological capabilities may have led to increased reliance on alliance forms that were apt to support learning processes, to the detriment of unilateral contractual modes. On the other hand, the radical nature of technological change and the risk of rapid technological obsolescence may have deterred relation-specific investments, reducing the need for equity forms.[13] Thus use of bilateral contractual alliances may have been the result of the balance between commitment to learning and flexibility, as is contended by authors inspired by real option theory. This indicates that this stream of theoretical literature offers an important addition to arguments suggested by TCE and the competence perspective to explain the organization of alliances.

Furthermore, the likelihood of choosing an equity form for a new alliance turns out to increase with the number of alliances previously established by partners between each other. A possible explanation for this result lies in the failure of this and previous studies to take into due account the effect of prior alliances on the underlying characteristics of newly established collaborations; in other words, empirical studies suffer from an omitted variables problem. In particular, if partners become confident of each other because of the positive experience of prior alliances, they may be prone to commit a larger amount of relation-specific resources to a new collaborative venture so as to increase its expected pay-off. With all else equal, this increases transaction costs and favors use of equity forms in spite of greater trust.[14] In this

[12] Nevertheless it has also been shown by previous studies that if technological activities are undertaken in isolation, i.e., independently of production, marketing, and distribution, alliances more often have a contractual form (Pisano *et al.*, 1988; Garcia Canal, 1996. For opposed results see Pisano, 1989). In addition, studies based on large cross-sectoral data sets highlight that the share of equity forms out of the total number of alliances decreases with the technological intensity of the industry in which alliances occur (Osborn and Baughn, 1990; Hagedoorn and Narula, 1996).

[13] While analyzing entry by telecommunication operators in Internet-based services in the first half of the 1990s, Colombo and Garrone (1998) show that bilateral contractual alliances were widely used by established firms in the early stages of the life cycle of such industry as a means for exploring untapped technological opportunities.

[14] Note also that equity joint ventures have higher termination costs than contractual relations, due to the partially unrecoverable nature of set-up costs. Thus firms are more willing to enter into such arrangements if they are confident about partners' competence and loyalty, as this reduces risks of failure. Such argument again implies that equity joint ventures will be

regard, information on such characteristics as the amount of tangible and intangible assets committed by the parties to a collaboration, or the number and professional characteristics of the employees that participate in the collaborative activities, would be very helpful in shedding new light on this issue. Unfortunately, in the present study, as in previous ones that were similarly based on secondary sources of information, such analytic data were not available.

CONCLUDING REMARKS

In this paper, I have analyzed the organizational form of 271 alliances that were established between each other by 67 of the world's largest firms in IT industries over the period 1983–86. The empirical findings show that in technological alliances bilateral contractual modes are relatively more frequent than both unilateral contractual modes and equity joint ventures. Moreover, the likelihood of choosing an equity form for such alliances increases with the divergence of the technological specialization of partner firms. Such results provide valuable new insights into the factors that influence the choice of governance mode of alliances. The latter one is germane to the competence perspective, and lends support to the view that bringing the idiosyncrasies of firms' capabilities to the fore is important in order to extend our understanding of alliance governance. The former one indicates that in accordance with the contention of real option theory, consideration of the trade-off between flexibility and commitment is an important addition to arguments proposed by both TCE and the competence perspective.

Nonetheless, I am aware of a number of limitations of this study, which also suggest avenues for future research. Three are worth mentioning here. First, the data used in this paper relate to large firms that operate in oligopolistic industries: whether the findings can be extended to other settings, for instance to agreements between large and small firms, is a matter of empirical testing. Second, as in most previous studies based on secondary sources of information, the motives for alliance formation are unknown. Accordingly, I rely on the evidence provided by previous studies in assuming learning-related motivations to be more important in technological alliances than in alliances that concentrate on production and commercial activities. Since some technological alliances have motives other than learning, such approximation biases towards null the estimated effect of the similarity of firms' technological specialization. If reliable information were available as to the objectives of alliances and the amount of relation-specific investments necessary to pursue such objectives, one could shed new light on the explanatory power of alternative theories as to the determinants of alliance form. Lastly, in this study I followed the recent empirical literature on alliance form in distinguishing between three broad alliance categories that have quite differentiated governance features. However, it is fair to recognize that the governance modes of alliances differ along a very large number of dimensions (see Oxley, 1997). Thus the above distinction is partially unsatisfactory, as there is substantial heterogeneity within each of the three categories considered (especially the two non-equity categories). More direct and fine-tuned consideration of the specific coordination and control mechanisms incorporated in different alliances, an approach that is slowly gaining ground in the empirical literature (see, for instance, Lerner and Merges, 1998; Anand and Khanna, 2000), would be very useful to gain further insights into the structuring of strategic alliances.

relatively more frequent (and unilateral contractual arrangements less frequent) if partners already have experience of successful collaborations between each other.

ACKNOWLEDGEMENTS

Financial support from Università di Pavia 2000 FAR funds and MIUR 2002 funds is gratefully acknowledged. I am indebted to Luigi Buzzacchi, John Cantwell, Sergio Mariotti, Bart Nooteboom, Torben Pedersen, Maurizio Sobrero, participants in the 1999 EAEE meeting and in seminars held at DRUID, Università di Pavia, Politecnico di Milano and Université Paris Sud for their helpful comments on earlier versions of this and related work. I would also like to thank two anonymous reviewers and the Associate Editor, whose challenging and constructive comments helped to substantially improve the paper. Responsibility for any error lies solely with the author.

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