Strategic Alliances and Interfirm Knowledge Transfer

David C. Mowery, Joanne E. Oxley, Brian S. Silverman

Strategic Management Journal, Volume 17, Issue Special Issue: Knowledge and the Firm (Winter, 1996), 77-91.

Stable URL:
http://links.jstor.org/sici?sici=0143-2095%28199624%2917%3C77%3ASAAIKT%3E2.0.CO%3B2-K

Strategic Management Journal, Vol. 17(Winter Special Issue), 77–91 (1996)

STRATEGIC ALLIANCES AND INTERFIRM KNOWLEDGE TRANSFER

DAVID C. MOWERY
Haas School of Business, University of California, Berkeley, California, U.S.A. and Canadian Institute for Advanced Research, Toronto, Ontario, Canada

JOANNE E. OXLEY
University of Michigan Business School, Ann Arbor, Michigan, U.S.A.

BRIAN S. SILVERMAN
Faculty of Management, University of Toronto, Toronto, Ontario, Canada

This paper examines interfirm knowledge transfers within strategic alliances. Using a new measure of changes in alliance partners' technological capabilities, based on the citation patterns of their patent portfolios, we analyze changes in the extent to which partner firms' technological resources 'overlap' as a result of alliance participation. This measure allows us to test hypotheses from the literature on interfirm knowledge transfer in alliances, with interesting results: we find support for some elements of this 'received wisdom'—equity arrangements promote greater knowledge transfer, and 'absorptive capacity' helps explain the extent of technological capability transfer, at least in some alliances. But the results also suggest limits to the 'capabilities acquisition' view of strategic alliances. Consistent with the argument that alliance activity can promote increased specialization, we find that the capabilities of partner firms become more divergent in a substantial subset of alliances.

INTRODUCTION

Recent literature on the role of firm-specific knowledge in competitive strategy has spawned several theoretical perspectives. The 'resource-based' view of the firm describes the business enterprise as a collection of sticky and difficult-to-imitate resources (Penrose, 1959; Barney, 1986; Wernerfelt, 1984), stressing the capture of rents through the protection and deployment of these resources. A related literature on 'dynamic capabilities' emphasizes the importance of change in the capabilities underpinning these resources (Teece, Pisano, and Shuen, 1997; Teece and Pisano, 1994), focusing in particular on the development, more than the exploitation, of firm-specific resources. Recent 'knowledge-based' views of the firm focus on knowledge as a key competitive asset, and emphasize the capacity of the firm to integrate tacit knowledge (Grant and Baden-Fuller, 1995; Conner and Prahalad, 1996).

A central factor in the 'dynamic capabilities' view of firm strategy is the acquisition of new capabilities through organizational learning. One device cited in this literature as an important tactic for organizational learning is the strategic alliance,[1] now an important element of contemporary firms' competitive strategies (Harrigan,

[1] 'The concept of dynamic capabilities as a coordinate management process opens the door to the potential for inter-organizational learning. Researchers . . . have pointed out that collaborations and partnerships can be vehicles for new organizational learning, helping firms to recognize dysfunctional routines, and preventing strategic blindspots' (Teece and Pisano, 1994: 545).

Key words: alliances; patents; technology transfer

CCC 0143–2095/96/S20077–15

1988; Hagedoorn and Schakenraad, 1990; Eisenhardt and Schoonhoven, 1996). A number of scholars have described the use of alliances by firms to acquire technology-based capabilities from alliance partners, and an extensive literature discusses the features of alliances and their participants that facilitate the flow of technology-based capabilities and other knowledge among partners (e.g., Kogut, 1988; Hamel, Doz, and Prahalad, 1989; Cohen and Levinthal, 1990; Hamel, 1991). Alliances may serve other purposes, however, and recent work on alliances and the role of firm-specific knowledge in firm strategy suggests additional motives and effects of alliance formation. Rather than using alliances to acquire capabilities, scholars suggest that firms use interfirm collaboration to gain *access* to other firms' capabilities, supporting more focused, intensive exploitation of existing capabilities within each firm (Grant and Baden-Fuller, 1995; Nakamura, Shaver, and Yeung, 1996).[2]

Empirical assessment of the importance and validity of these contrasting views, as well as broader empirical research on the role of knowledge within the firm and alliances within firm strategy, has been hampered by the widespread reliance on anecdotes and assertion, rather than statistical evidence. The lack of empirical work documenting the effects of participation in alliances on firms' technological capabilities is attributable in part to the difficulty of measuring the technological and other capabilities of firms. This paper analyzes the effects of interfirm knowledge transfers within strategic alliances on partner firms' technological capabilities, using a new measure of change in these capabilities. Using the citation patterns of partner firms' patent portfolios, we measure changes in the extent to which their technological resources 'overlap' with their partners' technological portfolios as a result of participation in an alliance. This methodology represents a significant advance on previous analysis of changing firm capabilities, which have relied on broad firm-level measures such as R&D spending or raw counts of patents issued to partner firms.

Our new measure allows us to test a number of hypotheses from the literature on interfirm transfer of capabilities in alliances. We find support for some elements of this 'received wisdom'—equity arrangements support greater transfer of technological capabilities (Kogut, 1988) and 'absorptive capacity' (Cohen and Levinthal, 1990) helps explain the effectiveness of technology-based capability transfer, at least in some types of alliances. But the empirical analysis also suggests that there are limits to the 'capabilities acquisition' view of alliances. Consistent with the view that alliance activity can lead to increased specialization, as firms access others' capabilities (rather than acquiring them or developing them internally), we find that the capabilities of partner firms become more divergent in a substantial subset of alliances.

Immediately below, we describe recent trends in alliance formation, summarizing current understanding of the motives for collaboration and the prominence of knowledge acquisition in recent discussions of strategic alliances. We then survey the literature on interfirm knowledge transfer in alliances, outlining some hypotheses based on this literature. This section is followed by a discussion of measures of technological capabilities and a description of the patent citation data used in our study. The following section briefly describes our data and empirical methods, and the next two sections of the paper present the empirical results and a concluding discussion of their implications.

TRENDS AND MOTIVES IN STRATEGIC ALLIANCES

Strategic alliances are not new phenomena—they have been important in international business since the turn of the century (Harrigan, 1986) when joint ventures were formed primarily as a vehicle for the exploitation of natural resources. Nonetheless, the rate of formation of alliances has increased significantly over the last two decades and the motives for their establishment have shifted, as alliances have become widespread in technology-intensive industries (e.g., semiconductors, computers, software, commercial aircraft) in which they were of little or no importance prior to 1975. In addition, the activities included in

[2] As Hamel points out, 'the crucial distinction between acquiring such skills in the sense of gaining *access* to them . . . and actually *internalizing* a partner's skills has seldom been clearly drawn . . . For the partners, an alliance may be not only a means for trading access to each other's skills—what might be termed *quasi-internalization*, but also a mechanism for actually acquiring a partner's skills—*de facto internalization*' (1991: 84; emphasis in original).

many of the alliances of the past 20 years, such as joint R&D and product development, can involve higher levels of knowledge exchange and technology transfer among participants.

Motives for the formation of these more recent alliances include the need to spread the costs and risks of innovation, as capital requirements for development projects in industries such as pharmaceuticals, telecommunications and commercial aircraft have risen (Mowery, 1988). Higher development costs and risks, along with a perceived shrinkage in product life-cycles, also mean that rapid penetration of foreign markets is more important than ever in many technology-intensive industries—something which may be more easily achieved through an alliance. Still other alliances focus on collaboration between users and suppliers of new products as a means of coordinating and formulating technical standards and 'dominant designs' (Grindley, 1995). Strategic motives also play a role in alliances that are formed to facilitate strategic coordination among competitors to increase market power (e.g., Porter and Fuller, 1986; Hagedoorn, 1993).

One of the most widely cited motives for collaboration, linked to many of those just described, is the acquisition of new technical skills or technological capabilities from partner firms (Mariti and Smiley, 1983; Hamel *et al.*, 1989; Shan, 1990; Hamel, 1991; Powell and Brantley, 1992; Mody, 1993; Khanna, 1996). Alliances have advantages over conventional contracts or markets for this task because firm-specific technological capabilities frequently are based on tacit knowledge and are subject to considerable uncertainty concerning their characteristics and performance. These features make it difficult to draft simple contracts governing the sale or licensing of such capabilities (Mowery, 1983; Pisano, 1990).[3] By combining some of the incentive structures of markets with the monitoring capabilities and administrative controls associated with hierarchy (internal organization), alliances can provide a superior means to gain access to technological and other complex capabilities. In fact, alliances run the gamut from fairly simple unilateral (i.e., 'technology for cash') contracts, such as licensing, through more complex contractually based arrangements, such as technology sharing and joint development agreements (which often include joint ownership or other organizational mechanisms for oversight and management), to 'pure' equity joint ventures, where ownership in a separately incorporated entity is shared by the partner firms (see Figure 1).[4]

The received wisdom on interfirm capabilities transfer implicitly assumes that the acquisition of technology-based capabilities is an important goal and effect of interfirm collaboration, and scholars have examined the factors that facilitate knowledge transfer among partner firms. This literature yields a number of testable empirical implications, which form the basis for the empirical hypotheses on the role of alliances in interfirm knowledge transfer that we discuss immediately below.

INTERFIRM KNOWLEDGE TRANSFER IN STRATEGIC ALLIANCES: RECEIVED WISDOM AND HYPOTHESES

Our empirical investigation focuses on transfer of technological capabilities among alliance partners. Specifically, we are interested in how collaboration changes the relationship between a firm's technological portfolio and those of its alliance partner(s). If collaboration results in the interfirm transfer of technological capabilities, then alliances should produce higher levels of technological 'overlap' among partner firms and increased similarity in their technology portfolios (Mowery, Oxley, and Silverman, 1997).

The previous literature provides a number of testable statements about factors influencing the extent of interfirm knowledge transfer in alliances. Kogut (1988) argues that the opportunities for interfirm transfer of capabilities afforded by different alliance structures influences the choice among them, since equity-based joint ventures are more effective vehicles for the transfer of tacit knowledge between the partners: 'Other forms of

[3] Other firm-specific capabilities include knowledge of specific markets or user needs, idiosyncratic, firm-specific 'routines', such as decision-making techniques or management systems, and complex networks for handling the marketing and distribution of products that include procedures for the documentation and analysis of user feedback.

[4] The 'other' category of alliance forms in Figure 1 includes second sourcing and coproduction agreements, joint research pacts and research corporations. 'Mixed modes' are primarily licensing agreements combined with equity exchanges.

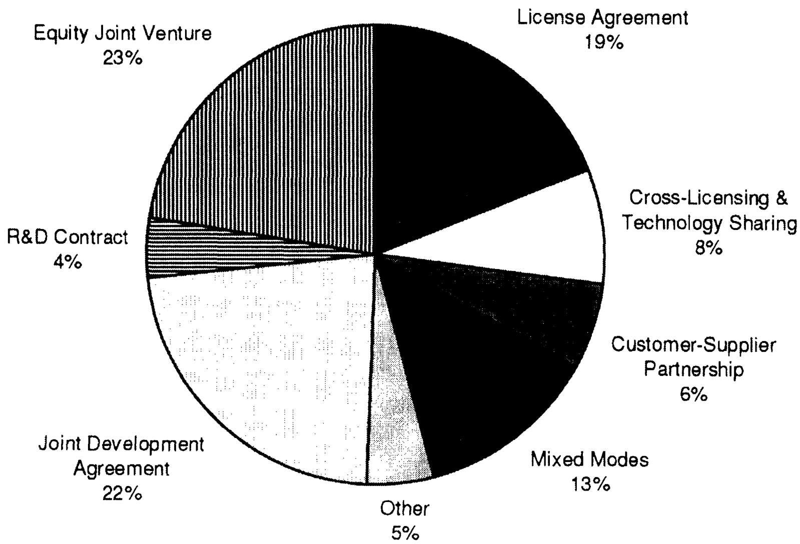

Figure 1. Variety in alliance forms
Source: CATI Database

transfer, such as through licensing, are ruled out . . . because the very knowledge that is being transferred is organizationally embedded' (Kogut, 1988: 323). This observation underpins our first hypothesis:

Hypothesis 1a: Interfirm transfer of technological capabilities will be enhanced in equity joint ventures; participants will display higher increases in technological overlap after formation of equity joint ventures than after formation of contract-based alliances.

An extension of this logic suggests that interfirm knowledge transfers should be more limited in 'unilateral' contract-based alliances, such as licensing agreements. The technology that is exchanged for cash payments in these undertakings generally is more tightly 'packaged' than is the case in bilateral contractual arrangements such as technology sharing or joint development agreements. As a result, 'unilateral' alliances create fewer opportunities for interfirm knowledge transfer.

Hypothesis 1b: Participants in unilateral contract-based alliances will display a lower increase in technological overlap after the formation of the alliance than participants in bilateral contract-based alliances.

However, the transfer of technological capabilities is by no means an assured outcome, even within equity-based joint ventures. Cohen and Levinthal (1990) argue that a necessary condition for a firm's successful exploitation of technological capabilities or knowledge outside its boundaries is development within the firm of the ability to absorb such capabilities. This 'absorptive capacity' requires that a firm have considerable in-house expertise that complements the technology activities of its alliance partner. Absorptive capacity results from a prolonged process of investment and knowledge accumulation within the firm, and its development is path-dependent; a firm's current absorptive capacity is influenced by its historic participation in specific product markets, lines of R&D, and other technical activities.[5]

There are few direct tests of the hypothesized influence of absorptive capacity, but the results of such tests (e.g., Gambardella, 1992) are broadly

[5] '. . . prior knowledge permits the assimilation and exploitation of new knowledge. Some portion of that prior knowledge should be very closely related to the new knowledge to facilitate assimilation . . . Accumulating absorptive capacity in one period will permit its more efficient accumulation in the next. By having already developed some absorptive capacity in a particular area, a firm may more readily accumulate what additional knowledge it needs in the subsequent periods in order to exploit any critical external knowledge that may become available' (Cohen and Levinthal, 1990: 135–136).

supportive of the argument that higher levels of absorptive capacity improve a firm's ability to exploit sources of technical knowledge outside its boundaries. Moreover, a parallel line of research in the broader technology transfer literature suggests that possession of relevant technical skills facilitates inward technology transfer (e.g., Rosenberg and Frischtak, 1991; Agmon and von Glinow, 1991). Still other research indicates that firms tend to establish alliances with firms that have overlapping technological capabilities (Mowery *et al.*, 1997).

A firm's absorptive capacity for learning from its alliance partners should depend on its endowment of relevant technology-based capabilities upon entering an alliance. R&D investment is a necessary (although not necessarily sufficient) condition for the creation of absorptive capacity—indeed, both Cohen and Levinthal's original test and Gambardella's subsequent examination of the issue use R&D intensity as a proxy for absorptive capacity. It is also plausible that larger firms have more diverse technological portfolios and therefore are more likely to possess technology that is 'relevant' to the alliance in question. Although both of these measures merit empirical testing, neither one provides the level of disaggregation and specificity of our patent-based measure of interfirm knowledge transfer (see below). We therefore include in our tests of the importance of absorptive capacity a more narrowly focused measure of absorptive capacity: the prealliance levels of technological overlap among the partners. Since absorptive capacity develops over time in a path-dependent fashion, substantial prealliance overlap between partners' technological portfolios should enhance their capacity to absorb new competencies from one another. Taken together, these arguments lead to the following hypotheses:

Hypothesis 2a: The extent of a firm's absorption of technological capabilities from its alliance partners will be positively related to its prealliance level of technological overlap wth partner firms.

Hypothesis 2b: The extent of a firm's absorption of technological capabilities from its alliance partners will be positively related to its R&D intensity.

Hypothesis 2c: The extent of a firm's absorption of technological capabilities from its alliance partners will be positively related to its size.

Another aspect of interfirm learning that is closely related to absorptive capacity and receives attention in the alliance literature concerns the extent to which firms enter into an alliance with the 'intent to learn' (Hamel, 1991). This argument appears in a number of critical commentaries on the alleged tendencies of U.S. firms to weaken their technological capabilities in alliances with foreign—primarily Japanese—firms (e.g., Reich and Mankin, 1986). Although there is evidence to the contrary (Mowery, 1988), some anecdotal and case-based research suggests the presence of asymmetries or differential rates of capability acquisition by U.S. and Japanese firms in alliances between them. Hamel *et al.* assert that in several U.S.–Japanese alliances, where the Japanese company emerged from an alliance stronger than its partner, 'the Japanese company had made a greater effort to learn' (1989: 134). Discussing a 20-year alliance with a Japanese firm, an executive of a U.S. industrial products company claimed: 'We established them in their core business. They learned the business from us, mastered our process technology ... and today challenge us outside Japan' (Hamel 1991: 86). Other evidence from Mansfield (1988), drawing on a survey of U.S. and Japanese firms, suggests that Japanese firms are more effective in commercializing innovations based on external sources of technology than are U.S. firms, a finding that is consistent with the presence within Japanese firms of a greater 'intent to learn' from external sources.

These examples may not be representative of the broader historical experience of U.S.–Japanese alliances, nor are the mechanisms that underpin the development and maintenance of such 'national traits' in business firms clearly articulated in this literature. The argument nevertheless has been extended to non-Japanese foreign firms: Hamel (1991) suggests that British firms share the alleged arrogance and lack of receptivity of U.S. firms and that French firms' ability to build competencies and learn from alliances approaches that of the Japanese. These arguments are based on extraordinarily broad generalizations from minimal evidence, but they occupy a prominent position in the received wisdom on alliances, and yield the following hypothesis:

Hypothesis 3: Japanese companies will absorb more of the technological capabilities of alliance partners than will firms from other countries.

Before discussing our methods for testing these hypotheses, we must address another issue. Significant interfirm knowledge transfer should be reflected in higher levels of technological overlap following the formation of an alliance. But participation in alliances need not always increase technological overlap. Instead, an alliance may enable one firm to gain access to key knowledge-based capabilities of another without internalizing or acquiring that capability, e.g., in an alliance in which one firm designs and the other manufactures an advanced semiconductor device. Among these alliances, interfirm knowledge transfer may be limited to only the codified information necessary to coordinate otherwise separable activities that draw on different 'knowledge domains' (Grant and Baden-Fuller, 1995). Thus, if an alliance enables its members to specialize in different but complementary areas of technology, partner firms may experience divergence in technological capabilities over the course of the alliance (reflected in lower levels of technological overlap), rather than convergence. Indeed, Nakamura *et al.* (1996) find evidence that in some cases joint venture partners display 'convergent development' (i.e., increasingly similar capabilities), but that other alliances produce divergence in the capabilities of partner firms.

If some alliances increase technological overlap while others promote specialization, then tests that assume convergent development through interfirm knowledge transfer (and consequently an unambiguous increase in postalliance technological overlap) are likely to produce inconclusive results, as was the case in Mowery *et al.* (1997). One test for alliance effects in the presence of both convergent and divergent development examines the *absolute value* of changes in technological overlap. If allying firms exhibit stronger changes in the extent of their technological overlap than nonallying firms—in either a positive (convergent) or negative (divergent) direction—then the changes in technological overlap by convergent and divergent alliances might offset one another, but the absolute value of these changes should be significantly larger than that of nonallying firms:

Hypothesis 4a: The presence of divergence and convergence within the alliance population will prevent the observation of a consistent postalliance increase in the technological overlap of alliance partner firms.

Hypothesis 4b: The absolute value *of the pre- vs. postcollaboration changes in technological overlap will be greater for alliance partners than for a similar sample of nonallying firm pairs over the same time period.*

MEASURING TECHNOLOGICAL CAPABILITIES AND INTERFIRM KNOWLEDGE TRANSFER

There is little empirical research on interfirm transfer of technological capabilities in strategic alliances, and most such work emphasizes case studies or small-scale surveys (for other examples, see Lyles, 1988; Sobrero and Roberts, 1996). These gaps reflect the lack of reliable measures of the technology-based capabilities of partner firms and a corresponding absence of measures of change in capabilities. Recent work on the resource-based view of the firm has faced similar difficulties. Although much of that research focuses on narrowly defined firm-specific capabilities in its conceptual discussion, most empirical tests of propositions in the resource-based view rely on broad measures that are subject to many interpretations. Corporate R&D intensity, for example, has frequently been used as a proxy for technological resources (e.g., Montgomery and Hariharan, 1991; Nakamura *et al.*, 1996), despite the fact that R&D intensity measures inputs to the creation of capabilities and indicates little if anything about resultant changes in capabilities.[6] More recent empirical

[6] For example, Nakamura *et al.* (1996) rely on measured changes in alliance members' R&D intensity and foreign sales (as a share of corporate sales) in assessing the 'divergent' or 'convergent' effects of alliance membership. However, it is difficult to interpret changes in such corporate-wide measures as tracking the effects of alliances that may span only a single line of business or a single product within a line of business.

work in this tradition has measured firms' technical resources with patent data (Silverman, 1996; Mowery *et al.*, 1997), which offers significant advantages over alternative measures such as R&D spending; patents are better measures of the output of R&D activities, the key concern for capabilities development. Moreover, patents provide a more disaggregated measure of changing technological portfolios for examining the effects of alliance activities (see Griliches, 1990; and Silverman, 1996, for further discussion).

Our empirical approach focuses on the citation patterns in a firm's patent portfolio, which allows us to observe changes in the relationship of one firm's technology portfolio to that of a partner firm. The measure shares some of the limitations of other patent-based measures (such as raw patent counts): the commercial importance of patents varies among industries and technologies, and firms therefore may display systematic differences in their propensity to seek patent protection for important technical advances. More importantly, patents are by definition examples of codified knowledge, and citation measures therefore may not capture flows of the tacit knowledge that often forms the basis for firm-specific capabilities. Tacit knowledge flows are virtually impossible to measure, however, and we assume that the codified knowledge represented by patents and tacit knowledge are complements, rather than substitutes, and that codified knowledge flows and the tacit knowledge flows of interest are closely linked. There is considerable support for this assumption (Patel and Pavitt, 1994).

When the U.S. Patent and Trademark Office grants a patent, the granting officer includes a list of all previous patents on which the granted patent is based.[7] Citations of prior patents thus serve as an indicator of the technological lineage of new patents, much as bibliographic citations indicate the intellectual lineage of academic research. As Firm_i acquires technological knowledge from its partner in an alliance, Firm_j, we should see a higher rate of citation of Firm_j's patents in new patents applied for by Firm_i. We refer to this as 'cross-citation rate (Firm_i, Firm_j).' More precisely, the measure is defined as follows:

$$\text{Cross-citation rate } (\text{Firm}_i, \text{Firm}_j) = \frac{\text{Citations to Firm}_j \text{ patents in Firm}_i\text{'s patents}}{\text{Total citations in Firm }_i\text{'s patents}}$$

The cross-citation rate provides a measure of the relative importance of Firm_j in Firm_i's external technology 'pool'. An increase in this measure is an indication of the degree to which Firm_i is acquiring technology-based capabilities from Firm_j, i.e., of the extent of interfirm knowledge transfer in the alliance and of the 'technological overlap' between the two companies.

EMPIRICAL ANALYSIS: SAMPLE AND METHODS

We tested our hypotheses by examining cross-citation rates for partners in bilateral alliances that involved at least one U.S. firm and were established during 1985 and 1986. The sample was taken from the Cooperative Agreements and Technology Indicators (CATI) data base, a comprehensive data set that contains information on over 9000 alliances involving some 5000 firms in many industries and countries (Hagedoorn and Schakenraad, 1990). This data set is based on systematic examination of secondary reports of alliance formation, primarily during the 1980s. Although coverage of the overall population is inevitably incomplete and significant biases remain, it is the most comprehensive and reliable source available for information on alliance activity in the global economy.

Each alliance in our sample involves at least one U.S. partner, since we expect interfirm knowledge transfers in these alliances to be more reliably associated with changing patterns of citation to U.S. patents. The years 1985–86 were chosen as the sample period because these were years in which alliance formation was at its height, and together the 2 years yield a sample size sufficient for the necessary statistical tests. Restricting the period to as few years as possible is important, in order to minimize the impact of overall trends in patenting and citation behavior. In addition, selecting a period in the mid-1980s allows straightforward computation of 'before' and 'after' patent citation rates from the available

[7] The patent officer is aided in this task by the patent applicant, whose application usually provides a list of all patents for relevant 'prior art'. It is in the applicants' interest to be forthcoming in this list because a more complete description of prior art is likely to reduce the prospects of an interference being declared during processing of a patent application.

patent data, which covers patents granted between 1975 and 1994 (see below).

The resulting sample contains a total of 792 alliances. Of these, 132 (16%) are equity joint ventures, 226 (29%) are unilateral contract-based alliances (i.e., technology licenses, R&D contracts and second-source agreements) and 434 (55%) are bilateral contract-based alliances (cross-licensing, joint development and technology sharing agreement, etc.). In 280 (35%) of the alliances, both partners are U.S. firms; 102 (13%) have a Japanese firm partnered with a U.S. firm; the remaining 410 (52%) involve a country from elsewhere in the world (but primarily Europe) partnered with a U.S. company.

In addition to our sample of alliance partners, we constructed a 'control sample' of nonallied firms by generating random pairings of firms in the CATI sample and eliminating any pairs which were listed as alliance partners anywhere in the CATI data base. This control sample of 858 firm pairs thus includes firms known to be active in alliances, and allows us to compare the change in citation patterns of alliance partners with those of a similar sample of nonallying firms, a procedure that is essential to tests of Hypotheses 4a and 4b.[8]

The patent data are drawn from the Micropatent data base, which contains all information recorded on the front page of every patent granted in the United States since 1975. This information includes the patent number, date of application, date of grant, company to whom the patent is assigned (if any) and references to prior patents for each granted patent. All patents assigned to the firms appearing in the sample were extracted from the Micropatent data base and corporate patent portfolios were constructed for each firm.

Many of the firms in the sample of alliances are multinational or multidivisional firms (or are subsidiaries of these firms), which poses a challenge when constructing the relevant patent portfolios. Since we focus on firm-specific capabilities, the relevent patent portfolio for the analysis is the portfolio of the entire firm, rather than for any single subsidiary. Since firms do not always assign a patent to the subsidiary in which the innovation took place and/or where it is used, construction of a firm-level patent portfolio is especially important. The first stage in the construction of our sample was to match firms in the sample with their relevant parent company, subsidiaries and/or 'sister' subsidiaries, using the 1985 edition of *Who Owns Whom* (North American Edition). The patent portfolio for each firm over the period 1975–94 was then created, by collecting the information on each patent issued to the relevant parent and all its subsidiaries. The 838 firms in the resulting data set controlled approximately 14,500 subsidiaries and more than 275,000 patents.

The result of the data collection and tabulation process is a series of firm-specific patent portfolios, detailing (for each patent held) the patent number, application date, issue date, and U.S. references (U.S. patents cited in the application). The number and vintage of the patents in each firm's portfolio vary considerably, and the number of patents cited in any single patent ranges from 0 to approximately 100, with a mean around 10. The total number of patents cited in $Firm_i$'s patents during the sample period thus varies from 0 to over 10,000. The patent cross-citation rates were computed for each partner in each alliance before and after collaboration.[9] Other data on firm characteristics in 1985 that are featured in the hypotheses (i.e., R&D spending and firm size, based on sales) or used as control variables (primary SIC code) were drawn from Compustat for U.S. firms and from Compact Disclosure's 'Worldscope Global' data base for non-U.S. firms.

[8] The limitations of this approach to control sample construction and alternative approaches are discussed at length in our earlier paper (Mowery *et al.*, 1997) where three different control samples, including both random pairing and matched pairs, were used. Here we use the firms from our sample of alliances to construct the control sample. This means that there are no significant differences in the overall characteristics of the two samples with respect to such features as industries or nationalities represented, the size distribution of firms within the sample, overall patenting and citation rates or changes in these rates. Full descriptive statistics are available from the authors upon request.

[9] The 'before' cross-citation rates are computed based on all patents applied for after January 1, 1979 and issued before December 31, 1984. Only citations to patents issued after 1975 are included in the calculation, since this is the earliest year for which patent data are available, and so for patents issued before that data, the assignee is unknown. 'After' citation rates refer to patents with applications dated after January 1, 1987 and issued prior to December 1, 1994. These cutoff dates were chosen to ensure that all applications for patents included in the 'before' calculation were in fact made before the collaboration began (i.e., before 1985) and those in the 'after' were after the latest alliance in the sample was established (i.e., after 1986).

Hypotheses 1–3 relate to the extent of changes in the cross-citation rates of alliance partners that occur as a consequence of interfirm transfer of capabilities. But Hypotheses 4a and 4b suggest that such transfer will not necessarily take place in divergent alliances, for which an entirely different logic of capability development may apply. Our research therefore proceeds in two stages: we first test Hypotheses 4a and 4b to establish whether the sample includes both divergent and convergent alliances, and then test the remaining hypotheses on the convergent sample. Table 1 contains definitions for all the variables used in the OLS and Tobit regression specifications and summarizes the models to be estimated for each hypothesis. The descriptive statistics in Table 2 reveal no systematic differences (except those related to citation rates) between the sample of convergent alliances and the overall alliance sample.

RESULTS

Our empirical results are summarized in Tables 3–5. They provide support for some but not all of the hypotheses, and some results challenge the received wisdom on interfirm transfer of capabilities in international alliances. We first tested for the presence of interfirm knowledge transfer or 'convergent development' in alliances (Hypotheses 4a and 4b) before going on to examine the factors that determine the extent of such transfers. Divergent development should be reflected in negative values of *DPCTCRSS* for the alliance in question, and these observations may cancel out the positive values of *DPCTCRSS* expected in convergent alliances. We investigated this issue by comparing citation rate changes for alliance partners with changes in the citation patterns of our control sample of 'nonallying' firms. Equation 1 in Table 3 shows the results

Table 1. Definition of variables and model specifications

Variable name	Definition
$PCTCRSS_{ij}$	Summed pre-1985 cross-citation rate for a given pair of firms *i* and *j*
$DPCTCRSS_{ij}$	Post-1986 cross-citation rate minus pre-1985 cross-citation rate for firms *i* and *j*
$ABSDCRSS_{ij}$	Absolute value of $DPCTCRSS_{ij}$
$FIRMLRN_{ij}$	Post-1986 cross-citation rate minus pre-1985 citation rate for firm *i* (citing to patents owned by firm *j*)
$ALLIES_{ij}$	dummy variable, = 1 if firms *i* and *j* are alliance partners, 0 otherwise
$EQUITY_{ij}$	dummy variable, = 1 if alliance involves equity, 0 otherwise
$UNILAT_{ij}$	dummy variable, = 1 if alliance is a unilateral contractual agreement, 0 otherwise
$US\text{-}nonUS_{ij}$	dummy variable, = 1 if alliance involves a non-U.S. partner, 0 otherwise
$SAMESIC_{ij}$	dummy variable, = 1 if alliance partners have the same 4-digit primary SIC code, 0 otherwise
$FORGNCO_i$	dummy variable, = 1 if firm i is non-U.S., 0 otherwise
$JAPANCO_i$	dummy variable, = 1 if firm i is Japanese, 0 otherwise
$PRECROSS_i$	Pre-1985 cross-citation rate for firm *i* (citing to patents owned by firm *j*)
$PRECRSS2_i$	Square of $PRECROSS_i$
$RNDINT_i$	R&D intensity (i.e., 1985 R&D expenses/sales) for firm *i*
$LNSALES_i$	Natural log of U.S. dollar value of 1985 sales for firm *i*
Hypothesis	**Model specification(s)**
H1a	$DPCTCRSS_{ij} = CONSTANT + EQUITY_{ij} + US\text{-}nonUS_{ij} + SAMESIC_{ij}$
H1b	$DPCTCRSS_{ij} = CONSTANT + UNILAT_{ij} + US\text{-}nonUS_{ij} + SAMESIC_{ij}$
H2a and H3	$FIRMLRN_{ij} = CONSTANT + EQUITY_{ij} + US\text{-}nonUS_{ij} + SAMESIC_{ij} + FORGNCO_i + JAPANCO_i + PRECROSS_i$
H2b and 2c	$FIRMLRN_{ij}$ = CONSTANT + $\text{EQUITY}_{ij} + US\text{-}nonUS_{ij} + SAMSESIC_{ij} + FORGNCO_i + JAPANCO_i + PRECROSS_i + RNDINT_i + LNSALES_i$
H4a	$DPCTCRSS_{ij} = CONSTANT + ALLIES_{ij} + US\text{-}nonUS_{ij} + SAMESIC_{ij}$
H4b	$ABSDCRSS_{ij} = CONSTANT + ALLIES_{ij} + US\text{-}nonUS_{ij} + SAMESIC_{ij}$

Table 2. Descriptive statistics

(a) Descriptive statistics for alliance sample (*ALLIES* = 1)

Variable	Mean	S.D.	Minimum	Maximum
PCTCRSS	0.568	2.532	0.000	50.000
DPCTCRSS	0.222	3.277	−50.000	40.005
ABSDCRSS	0.771	3.192	0.000	50.000
FIRMLRN	0.111	2.297	−50.000	40.000
EQUITY	0.168	0.374	0.000	1.000
UNILAT	0.283	0.451	0.000	1.000
US-nonUS	0.653	0.489	0.000	1.000
SAMESIC	0.075	0.264	0.000	1.000
FORGNCO	0.326	0.469	0.000	1.000
JAPANCO	0.104	0.306	0.000	1.000
PRECROSS	0.284	1.755	0.000	50.000
RNDINT	6.169	17.391	0.000	28.960
LNSALES	7.706	2.633	−0.646	11.529

(b) Descriptive statistics for 'convergent' alliance sample (i.e., *DPCTCRSS* > 0)

Variable	Mean	S.D.	Minimum	Maximum
PCTCRSS	0.376	1.125	0	10.166
DPCTCRSS	2.059	4.826	0.005	40.005
ABSDCRSS	2.059	4.826	0.005	40.005
FIRMLRN	1.030	3.514	−0.667	40.000
EQUITY	0.204	0.404	0	1
UNILAT	0.204	0.404	0	1
US-nonUS	0.670	0.471	0	1
SAMESIC	0.079	0.272	0	1
FORGNCO	0.335	0.473	0	1
JAPANCO	0.168	0.374	0	1
PRECROSS	0.186	0.762	0	10.000
RNDINT	7.371	14.596	0.007	31.739
LNSALES	8.005	2.489	0.861	11.529

Table 3. Results on divergence/convergence hypotheses (*t*-statistics in parentheses)

	1 (*DPCTCRSS*)	2 (*ABSDCRSS*)
INTERCEPT	0.358***	0.364***
	(3.305)	(3.442)
ALLIES	0.058	0.619***
	(0.433)	(4.697)
US-nonUS	−0.326*	−0.201*
	(−2.634)	(−1.662)
SAMESIC	−0.060	−0.179
	(−0.298)	(−0.916)
n	1650	1650
F-statistic	2.343*	8.131***

*** Significant at 0.01 level; ** significant at 0.05 level; * significant at 0.1 level.

Table 4. Results on alliance structure hypotheses (chi-squares in parentheses)

	3 (*DPCTCRSS*)	4 (*DPCTCRSS*)
INTERCEPT	−2.223***	−2.782***
	(61.493)	(36.422)
EQUITY	1.403***	
	(11.385)	
UNILAT		−1.325**
		(6.311)
US-nonUS	−0.503	−0.091
	(2.304)	(0.034)
SAMESIC	−1.10***	−1.273**
	(8.032)	(4.603)
Scale parameter	5.658	4.946
n	191	147
Log likelihood	−1046.9	−857.1

of OLS estimation on a pooled sample of 792 alliances (*ALLIES* = 1) and 858 nonallying pairs (*ALLIES* = 0).

A control variable, *SAMESIC*, which denotes alliances made up of firms from the same 4-digit SIC, is included in this and other specifications to control for the effects of competition among alliance members in product markets and potential similarity in alliance members' product lines, which otherwise could result in spurious high levels of cross-citation. We also anticipate that 'domestic' alliances, in which all member firms share a common home country, are likely to produce different patterns of interfirm technology transfer and learning than that found in 'international' alliances. The less forbidding barriers of culture, language, educational background, and distance associated with domestic alliances should result in higher levels of knowledge transfer. Since our sample includes a large number of 'U.S.–U.S.' and 'U.S.–non-U.S.' alliances, we inserted another control variable. *Us-nonUS*, to distinguish alliances in which U.S. firms were teamed with foreign enterprises.

Consistent with Hypothesis 4a, we find that the coefficient on *ALLIES* in Equation 1 is very

Table 5. Results on absorptive capacity hypotheses (*t*-statistics in parentheses)

	5 (*FIRMLRN*)	6 (*FIRMLRN*)
INTERCEPT	1.431***	4.506***
	(4.521)	(5.481)
EQUITY	1.076**	0.301
	(2.448)	(0.563)
US-nonUS	−1.280***	−0.648
	(−2.944)	(−1.401)
SAMESIC	0.110	0.088
	(0.252)	(0.089)
FORGNCO	0.608	0.647
	(1.133)	(0.594)
JAPANCO	−0.700	−0.492
	(−1.133)	(−0.349)
PRECROSS	0.681***	1.812***
	(2.871)	(5.228)
RNDINT		−0.015
		(−1.228)
LNSALES		−0.443***
		(−4.590)
n	382	155
F-statistic	4.327***	6.857***

small and stastistically insignificant.[10] *US-nonUS* has a negative and significant coefficient, indicating that international alliances produce less interfirm exchange of technological capabilities, and the coefficient for *SAMESIC* is insignificant. There is no consistently positive pattern of interfirm learning in our overall alliance sample. The absence of any consistent pattern of change in citation rates can be explained, however, by the presence of both 'convergent' and 'divergent' alliances in our sample (Equation 2). When the *absolute value* of the difference between post- and prealliance cross-citation rates, *ABSDCRSS*, is regressed on the same variables in an OLS estimation, we obtain a larger and statistically significant coefficient for *ALLIES*, along with a negative and marginally significant coefficient for *US-nonUS* and an insignificant coefficient for *SAMESIC*.

Participation in alliances thus produces significant absolute-valued changes in firms' cross-citation of partner-firm patents, supporting Hypothesis 4b. These results provide some support for the arguments in Nakamura *et al.* (1996) that participation in an alliance may produce either convergence of capabilities through interfirm knowledge transfer or divergence through complementary specialization. In addition, these results suggest that international alliances result in less interfirm knowledge exchange or specialization, reflecting the greater logistical and cultural complexities of managing such undertakings.

The remainder of our empirical analysis focuses on factors that influence the extent of interfirm transfer of technology-based capabilities. Accordingly, we restrict our analysis to alliances in which such transfers take place, i.e., those exhibiting technological 'convergence' (*DPCTCRSS* > 0). The determinants of the presence and degree of 'convergence' or 'divergence' in alliance partners' technology-based capabilities are important issues, but lie beyond the scope of this paper. The results reported in Table 4 exclude negative values of the dependent variable (*DPCTCRSS*) and therefore are estimated with the Tobit technique. The specifications address the impact of alliance structure on patterns of interfirm knowledge and capabilities transfer (Hypotheses 1a and 1b) in the 191 alliances characterized by convergent development.

Equation 3 regersses *DPCTCRSS* on *EQUITY* (a dummy variable indicating alliances that involve shared equity by partner firms) as well as *US-nonUS* and *SAMESIC*. Consistent with Hypothesis 1a, the positive and significant coefficient for *EQUITY* implies that equity-based joint ventures support higher levels of interfirm knowledge and capabilities transfer than contract-based alliances. The Tobit coefficient for *SAMESIC* negative and significant, suggesting that convergent alliances involving firms in the same product lines or markets experience lower levels of interfirm knowledge transfers than those spanning 4-digit SICS. The coefficient for *US-nonUS* remains negative, but is no longer significant at even the 0.1 confidence level.[11]

[10] This result is similar to findings from our earlier paper, which analyzed a small sample of alliances (Mowery *et al.*, 1997). A separate test (not reported here) of another hypothesis from the earlier paper on these data also replicated the finding that prealliance cross-citation rates positively and significantly influence partner choice in alliances.

[11] Estimation of the same model and a similar one using *ABSDCRSS* as the dependent variable for the full sample of 792 alliances (using OLS) produces interesting results (not

Equation 4 in Table 4 tests Hypothesis 1b, which argues that 'unilateral' contracts will result in lower levels of interfirm transfer of technological capabilities than bilateral contract-based (nonequity) alliances. Using the sample of 147 nonequity alliances exhibiting convergent development, we regressed *DPCTCRSS* on *UNILAT, SAMESIC* and *US-nonUS*. The results are supportive of our hypothesis; *UNILAT* has a negative, statistically significant coefficient (at the 0.05 level), and the coefficients for *US-nonUS* and *SAMESIC* are similar to the results reported in earlier specifications. 'Unilateral' alliances, which can be placed at the 'market' end of a 'market–hierarchy' continuum of alliance forms, thus seem to support lower levels of interfirm knowledge transfer, consistent with the earlier discussion of the difficulties of acquiring technological capabilities through market-based mechanisms. The results support other empirical and theoretical work that argues that the structure and governance of alliances are influenced by and in turn influence their content and activities (Oxley, 1996).[12]

Results for the remaining hypotheses (Hypotheses 2a–c and 3) are contained in Table 5. The dependent variable in each of the two specifications is *FIRMLRN*, which measures changes in the cross-citation behavior of a single firm in an alliance (see Table 1); negative values are included, and Equations 5 and 6 therefore are estimated with OLS. Equation 5 tests for the effects of 'absorptive capacity' on firms' ability to learn from alliance partners. Since R&D and sales data are available for a small subset of our 838 observations (due to the presence of a large number of foreign or privately held firms), this model uses only *PRECROSS* (firm$_i$'s pre-1985 cross-citations of its partner firm's patents) as a measure of absorptive capacity. The coefficient for *PRECROSS* is positive and statistically significant, supporting Hypothesis 2a concerning the importance of absorptive capacity for firms' ability to extract technological capabilities and knowledge from alliance partners (the size and significance of the coefficients for the other 'control' variables, *SAMESIC* and *US-nonUS*, are largely consistent with previous OLS results).[13]

Equation 6 includes measures of firm$_i$'s R&D intensity (*RNDINT*) and the natural logarithm of its sales (*LNSALES*) as additional measures of absorptive capacity. The coefficient for *PRECROSS* remains positive and significant, but the other results for Equation 6 do not support Hypothesis 2b or 2c—the coefficient for *RNDINT* is negative and nonsignificant, while that for *LNSALES* is negative and significant. Larger firms within this sample thus appear to absorb fewer capabilities from their alliance partners, controlling for other characteristics of absorptive capacity and alliances, while relatively R&D-intensive firms do not exhibit superior capabilities absorption in alliances, *ceteris paribus*. Due in part to the reduction in sample size, the coefficients for both *EQUITY* and *US-nonUS* also are not significant in Equation 6, although their signs remain unchanged.

Our final hypothesis on the determinants of the extent of interfirm knowledge transfer (Hypothesis 3) tested the arguments of Hamel *et al.* (1989) that Japanese firms exhibit consistently superior abilities to learn 'more' through alliances with U.S. firms than is true of firms from other countries. Equations 5 and 6 shed light on this issue: once we control for the lower overall

reported here in detail; available from the authors on request) that bear on the convergence/divergence dichotomy. The specification that uses *DPCTCRSS* as the dependent variable again shows a positive and significant effect for *EQUITY*. Estimation of a model using the absolute value of the change in partner firms' cross-citations (*ABSDCRSS*) as the dependent variable yields a coefficient for *EQUITY* that is slightly smaller in magnitude and has a larger standard error. Taken together, these results suggest that firms participating in equity- based joint ventures tend to exhibit 'convergent', rather than 'divergent' development of technological capabilities.

[12] The negative coefficient obtained when this model was run on the complete sample of nonequity alliances (results not shown) suggests that unilateral alliances may in fact support specialization, as defined by Nakamura *et al.* (1996). Firms participating in 'unilateral' alliances exhibit divergence in their patent cross-citation behavior, meaning that participation in such alliances is consistent with a decision to buy (i.e., license), rather than develop the capabilities necessary to 'make' components of their technology portfolios.

[13] Other work with patent cross-citations (Mowery *et al.*, 1997) found that firms tend to team with alliance partners that have similar technological portfolios, but there are 'decreasing returns to similarity', i.e., we obtained a negative coefficient for the square of prealliance cross-citations in a model analyzing alliance partner choice. This tendency may apply to absorptive capacity as well: the effects of prealliance technological overlap on knowledge transfer among partner firms may be nonlinear, as opportunities for such transfer diminish at higher levels of similarity in the technological portfolios of alliance partners. We explored this possibility by adding *PRECRSS2* (the square of *PRECROSS*) to our model. Although we obtained the 'correct' (i.e., negative) coefficient on *PRECRSS2*, the coefficient failed all tests of statistical significance.

knowledge transfers achieved within *US-nonUS* alliances (compared with those involving only U.S. firms), we find that foreign firms (*FORGNCO*) do not display significantly lower levels of capabilities acquisition than U.S. firms. Furthermore, the results in Table 5 provide no support for the supposedly superior learning abilities of Japanese companies. Japanese companies (designated by the dummy variable *JAPANCO*) have, if anything, a lower ability to acquire capabilities from alliances with U.S. firms than do other U.S. firms' foreign alliance partners: the coefficient on *JAPANCO* is consistently negative, although it fails to pass conventional tests of statistical significance. Cross-national differences in the ability to acquire capabilities through alliances thus appear to be quite small, and if such a difference exists at all for Japan, it is precisely the opposite of that articulated in the 'received wisdom'.

CONCLUSION

Research on resource- and knowledge-based views of the firm, along with related work on interfirm alliances, has been hampered by the lack of measures of firm-specific capabilities. These difficulties have meant that discussion of the motives and effects of alliance activity has proceeded in a virtual empirical vacuum, and competing views of alliance activity have rarely been brought into sharp focus. This paper uses a novel technique for measuring change in firms' technological capabilities that allows us to track the effects of alliance activity on interfirm knowledge transfers and the transfer of technology-based capabilities from one partner to another.

Our empirical results support two propositions from the 'received wisdom' on interfirm knowledge transfers in alliances. We find that equity joint ventures appear to be more effective conduits for the transfer of complex capabilities than are contract-based alliances such as licensing agreements, consistent with Kogut (1988). Furthermore, lower levels of transfer occur in unilateral contracts than in bilateral nonequity arrangements. This result in turn provides support for the argument that the structure and content of alliances are jointly determined, and that alliances nearer the 'hierarchy' end of the 'market–hierarchy' continuum (Oxley, 1996) outperform alternatives in supporting interfirm learning, *ceteris paribus*.

The analysis also provides some support for the importance of 'absorptive capacity' in the acquisition of capabilities through alliances and bolsters the argument that experience in related technological areas is an important determinant of absorptive capacity (Cohen and Levinthal, 1990). A firm's ability to absorb capabilities from its alliance partner depends on the prealliance relationship between the two firms' patent portfolios, consistent with Cohen and Levinthal's characterization of absorptive capacity as a quality that is both firm-specific and path-dependent. Other measures of absorptive capacity perform poorly, however, and further research on this issue requires better measures of the structure and activities of individual alliances.

Our results also suggest the need for a richer conceptual framework in considering the effects of alliance activity on firm-specific knowledge and capabilities. Significant interfirm transfer of knowledge and technological capabilities occurs in only a subset of alliances, characterized by 'convergent development' (Nakamura *et al.*, 1996). The presence of some alliances in our sample in which the firms display 'divergent development', i.e., declining technological overlap, suggests that some alliances are vehicles for accessing rather than acquiring capabilities. The 'learning' that takes place within alliances thus appears to be more complex than most of the literature on this topic suggests, underlining the need for better definitions of learning in theoretical discussions of alliance activity and highlighting this as an area ripe for further study.

Finally, with respect to an issue that is widely cited in popular commentary on international alliances, we find little evidence that Japanese firms have siphoned off important technological capabilities from their U.S. alliance partners, thereby contributing to the 'hollowing out' of U.S. corporations. Perhaps reflecting their new status of technological leadership (or parity) in many industries, Japanese partners now offer their alliance partners valuable opportunities for learning that our data suggest have been exploited by U.S. firms. In one other respect, however, our results do tend to support the conventional wisdom: U.S. firms' alliances with non-U.S. firms seem to result in lower levels of interfirm knowledge transfer than those involving only U.S. companies. This finding is consistent with arguments made by Gulati (1996) and others about the obstacles to interfirm knowledge transfer created by distance, cultural differences, and other factors.

Despite a substantial literature on these topics, the empirical analysis of strategic alliances, firm-specific capabilities, and interfirm knowledge transfers continues to rely heavily on case studies and imperfect indicators of the underlying phenomena. The empirical analysis reported here is one of the first systematic tests of various assertions in this literature. In addition to shedding light on these specific issues, this study's measures of changing firm-specific technological capabilities have considerable promise for broader application to the analysis of firm strategy and technological innovation, and may provide a stronger empirical underpinning for this provocative conceptual literature.

ACKNOWLEDGEMENTS

We gratefully acknowledge the comments and suggestions of Bernard Yeung and the Guest Editors. Research for this paper was supported by the Alfred P. Sloan Foundation, the U.S. Air Force Office of Scientific Research, and the Canadian Institute for Advanced Research.

REFERENCES

Agmon, T. and M. von Glinow (eds.) (1991). *Technology Transfer in International Business*. Oxford University Press, Oxford, U.K.

Barney, J. B. (1986). 'Strategic factor markets: Expectations, luck, and business strategy', *Management Science*, **32** (10), pp. 1231–1241.

Cohen, W. M. and D. A. Levinthal (1990). 'Absorptive capacity: A new perspective on learning and innovation', *Administrative Science Quarterly*, **35**, pp. 128–152.

Conner, K. and C. K. Prahalad (1996). 'A resource-based theory of the firm: Knowledge versus opportunism', *Organization Science*, **7**(5), pp. 477–501.

Eisenhardt, K. M. and C. B. Schoonhoven (1996). 'Resource-based view of strategic alliance formation: Strategic and social effects in entrepreneurial firms', *Organization Science*, **7** (2), pp. 136–148.

Gambardella, A. (1992). 'Competitive advantages from in-house scientific research: The U.S. pharmaceutical industry in the 1980s', *Research Policy*, **21**, pp. 391–407.

Grant, R. M. and C. Baden-Fuller (1995). 'A knowledge-based theory of inter-firm collaboration', *Best Paper Proceedings 1995*, Academy of Management, pp. 17–21.

Griliches, Z. (1990). 'Patent statistics as economic indicators', *Journal of Economic Literature*, **28**, pp. 1661–1707.

Grindley, P. (1995). *Standards, Strategy and Policy: Cases and Stories*. Oxford University Press, New York.

Gulati, R. (1996). 'Social structure and alliance formation patterns: A longitudinal analysis', *Administrative Science Quarterly*, **40**, pp. 619–652.

Hagedoorn, J. (1993). 'Understanding the rationale of strategic technology partnering: Interorganizational modes of cooperation and sectoral differences', *Strategic Management Journal*, **14** (5), pp. 371–385.

Hagedoorn, J. and J. Schakenraad (1990). 'Inter-firm partnerships and co-operative strategies in core technologies'. In C. Freeman and L. Soete (eds.), *New Explorations in the Economics of Technical Change*. Frances Pinter, London, pp. 3–37.

Hamel, G. (1991). 'Competition for competence and inter-partner learning within international strategic alliances', *Strategic Management Journal*, Summer Special Issue, **12**, pp. 83–103.

Hamel, G., Y. Doz and C. K. Prahalad (1989). 'Collaborate with your competitors—and win', *Harvard Business Review*, **67** (1), pp. 133–139.

Harrigan, K. (1986). *Managing for Joint Venture Success*. Lexington Books, Lexington, MA.

Harrigan, K. (1988). 'Joint ventures and competitive strategy', *Strategic Management Journal*, **9** (2), pp. 141–158.

Khanna, T. (1996). 'Winner-take-all alliances', Harvard Business School Working Paper, No. 96-033.

Kogut, B. (1988). 'Joint ventures: Theoretical and empirical perspectives', *Strategic Management Journal*, **9** (4), pp. 319–332.

Lyles, M. A. (1988). 'Learning among joint venture sophisticated firms', *Management International Review*, **28**, pp. 85–98.

Mansfield, E. (30 September 1988). 'Industrial innovation in Japan and the United States', *Science*, pp. 1769–1774.

Mariti, P. and R. H. Smiley (1983). 'Co-operative agreements and the organization of industry', *Journal of Industrial Economics*, **31** (4), pp. 437–451.

Mody, A. (1993). 'Learning through alliances', *Journal of Economic Behavior and Organization*, **20**, pp. 151–170.

Montgomery, C. A. and S. Hariharan (1991). 'Diversified expansion by large established firms', *Journal of Economic Behavior and Organization*, **15**, pp. 71–89.

Mowery, D. C. (1983). 'The relationship between intrafirm and contractual forms of industrial research in American manufacturing, 1900–1940', *Explorations in Economic History*, **20**, pp. 351–374.

Mowery, D. C. (ed.) (1988). *International Collaborative Ventures in U.S. Manufacturing*. Ballinger, Cambridge, MA.

Mowery, D. C., J. E. Oxley and B. S. Silverman (1997).

'Technological overlap and interfirm cooperation: Implications for the resource-based view of the firm', *Research Policy*, forthcoming.

Nakamura, M., J. M. Shaver and B. Yeung (1996). 'An empirical investigation of joint venture dynamics: Evidence from US–Japan joint ventures', *International Journal of Industrial Organization*, **14**, pp. 521–541.

Oxley, J. E. (1996). 'Appropriability hazards and governance in strategic alliances: A transaction cost approach', University of Michigan working paper, #9602-23.

Patel, P. and K. L. R. Pavitt (1994). 'Technological competencies in the world's largest firms: Characteristics, constraints and scope for managerial choice', unpublished manuscript, Science Policy Research Unit, University of Sussex, Brighton, U.K.

Penrose, E. T. (1959). *The Theory of the Growth of the Firm*. Wiley, New York.

Pisano, G. P. (1990). 'The R&D boundaries of the firm: An empirical analysis', *Administrative Science Quarterly*, **35** (1), pp. 153–176.

Porter, M. E. and M. B. Fuller (1986). 'Coalitions and global strategy'. In M. E. Porter (ed.), *Competition in Global Industries*. Harvard Business School Press, Boston, MA, pp. 315–344.

Powell, W. and P. Brantley (1992). 'Competitive cooperation in biotechnology: Learning through networks?' In N. Nohria and R. Eccles (eds.), *Networks and Organizations: Structure, Form and Action*. Harvard Business School Press, Boston, MA, pp. 365–394.

Reich, R. B. and E. D. Mankin (1986). 'Joint ventures with Japan give away our future', *Harvard Business Review*, **64** (2), pp. 78–86.

Rosenberg, N. and C. Frischtak (1991). In N. Rosenberg and C. Frischtak (eds.), *International Technology Transfer: Concepts, Measures and Comparison*. Praeger, New York.

Shan, W. (1990). 'An empirical analysis of organizational strategies by entrepreneurial high-technology firms', *Strategic Management Journal*, **11** (2), pp. 129–139.

Silverman, B. S. (1996). 'Technical assets and the logic of corporate diversification', unpublished doctoral dissertation, Haas School of Business, University of California, Berkeley, CA.

Sobrero, M. and E. B. Roberts (1996). 'The trade-off between efficiency and learning in inter-organizational relationships', MIT Sloan School of Management working paper, WP#3896.

Teece, D. J., G. Pisano and A. Shuen (1997). 'Dynamic Capabilities and Strategic Management', *Strategic Management Journal*, **18**, forthcoming.

Teece, D. J. and G. Pisano (1994). 'The dynamic capabilities of firms: an introduction', *Industrial and Corporate Change*, **3**, pp. 537–556.

Wernerfelt, B. (1984). 'A resource-based view of the firm', *Strategic Management Journal*, **5** (2), pp. 171–180.