

Overcoming Local Search Through Alliances and Mobility

Lori Rosenkopf • Paul Almeida

The Wharton School, University of Pennsylvania, Philadelphia, Pennsylvania 19104-6370

McDonough School of Business, Georgetown University, Washington, D.C. 20057

rosenkopf@wharton.upenn.edu • almeidap@georgetown.edu

Recent research suggests that, due to organizational and relational constraints, firms are limited contextually—both geographically and technologically—in their search for new knowledge. But distant contexts may offer ideas and insights that can be extremely useful to innovation through knowledge recombination. So how can firms reach beyond their existing contexts in their search for new knowledge? In this paper, we suggest that two mechanisms—alliances and the mobility of inventors—can serve as bridges to distant contexts and, thus, enable firms to overcome the constraints of contextually localized search.

Through the analysis of patent citation patterns in the semiconductor industry, we first demonstrate both the geographic and technological localization of knowledge. We then explore if the formation of alliances and mobility of active inventors facilitate interfirm knowledge flows across contexts. We find that mobility is associated with interfirm knowledge flows regardless of geographic proximity and, in fact, the usefulness of alliances and mobility increases with technological distance. These findings suggest that firms can employ knowledge acquisition mechanisms to fill in the holes of their existing technological and geographic context.

(Knowledge; Alliances; Mobility; Patents; Localization)

1. Introduction

Organizations innovate, in part, through combinations of existing and new knowledge (Kogut and Zander 1992). They must, therefore, often turn to external sources to gain new ideas, insights, and expertise. This ability to acquire this knowledge from external entities is, however, limited by an organization's own experience and expertise (Nelson and Winter 1982). Scholars have come to agree that a firm's search for new knowledge is technologically and geographically bounded (Jaffe et al. 1993, Stuart and Podolny 1996).

Recent research emphasizes the importance of knowledge recombinations across technologies (Rosenkopf and Nerkar 2001, Fleming 2001) and geographic regions (Song et al. 2001). But if knowledge flows between technologically and geographically

proximate firms, how can companies overcome localization, and reach out for distant and, perhaps, unique knowledge? This paper suggests that two mechanisms—the mobility of inventors and the formation of strategic alliances—can enable firms to overcome geographic and technological constraints.

We explore how a cohort of semiconductor firms uses these mechanisms to draw on the knowledge stocks of other firms. The study employs patent citation data to observe this phenomenon. We pay particular attention to whether contextual factors (geographic location and technological expertise) influence the efficacy of the mechanisms. Thus, a key contribution of this paper rests in its ability to explore both proximal and distant influences on interfirm knowledge flows systematically and simultaneously.

2. Contexts, Mechanisms, and Knowledge Flows

Studies in evolutionary economics highlight the importance of path dependence in the innovative process (Nelson and Winter 1982, Dosi 1988). These studies suggest that the results of past searches for knowledge become the natural starting points for new searches, as firms rely on their own experience and established knowledge bases to determine what is important and useful. Research in organizational learning (March and Simon 1958, Cyert and March 1963) also makes a similar point regarding the search for new knowledge. This literature suggests that boundedly rational decision makers rely on established organizational practices to drive the search for knowledge. Routines or “socially constructed programs of action” are relatively stable and greatly influenced by the experience and history of the firm and the individuals therein (Nelson and Winter 1982, Baum et al. 2000). Firms, thus, recognize and absorb external knowledge close to their existing knowledge base (Cohen and Levinthal 1990). Hence, even as firms seek to expand their knowledge stocks by looking externally, the resultant search processes are restricted to familiar and proximate areas. Thus, the search for new knowledge is often restricted to a firm’s technological or geographic context.

2.1. Contextual Localization of Knowledge

We use the term *context* to refer to technological or geographic landscape in which a firm operates. Technological and geographical contexts derive from each firm’s accumulated decisions regarding technological and locational choices.

Technological Similarity. Studies of innovation and technological development suggest that the tendency toward technologically local search is pervasive. For instance, Helfat’s (1994) study of petroleum firms shows that the allocation of R&D spending among various lines of technology varies little across time. Martin and Mitchell (1998) show that new product introductions are heavily influenced by the designs of existing products. While technologically local search is attributed primarily to internal organizational constraints, a variety of interfirm relational

mechanisms reinforce this tendency. For example, firms and their employees participate in cooperative technical organizations such as technical committees (Rosenkopf and Tushman 1998, Rosenkopf et al. 2001), jointly author technical papers (Liebeskind et al. 1996), and form alliances (Mowery et al. 1996). Thus, they interact most frequently with other firms and individuals with similar technological expertise. Social networks emerge between professionals with common technological interests (von Hippel 1987), and these external relationships reinforce the internal organizational emphasis toward local search.

Empirical studies of patent data suggest a relationship between technological similarity and knowledge flows without testing directly for this relationship. For example, Stuart and Podolny (1996) construct a technological landscape using common patent citations, and show that every major Japanese semiconductor firm, save one, maintained a similar position on this landscape across a 10-year period. This implies that firms continue to draw upon the knowledge stocks of firms most technologically similar to them.

HYPOTHESIS 1. Technological similarity increases the likelihood that a focal firm will draw upon the knowledge stock of another firm.

Geographic Similarity. Other studies of innovation and technology diffusion point to the geographic localization of knowledge. Jaffe et al. (1993) analyzed patent citation data to demonstrate that firms and universities acquire knowledge from others in geographically proximate locations. A key reason for geographically localized knowledge flows, research suggests, is the establishment of interfirm linkages between firms in the region (Saxenian 1990). These relational linkages may be formalized, such as alliances and supply relationships (von Hippel 1988) or informal, such as regional social networks (Rogers and Larsen 1984) and mobility of engineers (Almeida and Kogut 1999). Case studies document extensive information flows through regional clusters in Italy (Piore and Sabel 1984), Germany (Herigel 1993), and Silicon Valley (Saxenian 1990). These studies suggest that geographic proximity reduces the cost and increases the frequency of personal contacts that build social relations between players in a

network, thereby facilitating the flow of knowledge. Firms exploit these regional relationships to access knowledge from other local firms. Organizations reinforce the tendency for geographically local search through the establishment of boundary spanners and gatekeepers with local experience (Allen 1983), as well as by hiring regional experts from neighboring firms (Almeida and Kogut 1997). Thus, as in the case of technology, the underlying reason for geographic local search is both organizational and relational in nature.

HYPOTHESIS 2. Geographic proximity increases the likelihood that a focal firm will draw upon the knowledge stock of another firm.

Given the tendency for localized search, the organizational characteristics and external relationships are self-reinforcing and hard to change. Not surprisingly, Sorenson and Stuart's (2000) analysis of semiconductor patent citations suggests greater localization of the knowledge search process across time. These studies suggest a second point—given the localness of search, a firm's technological area of expertise or technological context may be relatively stable and difficult to change. Similarly, geographic context is relatively stable, because it is not mere location that matters to interfirm learning, but the more challenging process of getting embedded through the establishment of relationships in regional networks (Saxenian 1994). Thus, firms to a large extent are bound to and limited by the technological and geographic contexts in which they find themselves.

Of course, local, contextually bounded search has some advantages. It restricts the breadth and, therefore, the cost of the search process. Geographically and technologically proximate search also results in the acquisition of knowledge that can be more easily recognized and managed by the organization's existing routines and members. Despite these advantages, recent studies in the area of strategic management suggest that given technological change and the dynamic nature of competition, firms must move beyond local search to successfully compete across time. For example, Porter (1990) points to the emergence of geographically dispersed but specialized regions, in various technologies and industries, emphasizing the need for geographically distant

search. Kim and Kogut (1996) show that the dynamic of competition has encouraged semiconductor firms to diversify across technological subfields to maintain their competitive edge. Rosenkopf and Nerkar (2001) demonstrate that external exploration in distant technological domains yields innovations with more impact on a broader set of technological areas. Studies like these support March's (1991) suggestion that firms balance local search (exploitation) with more distant search (exploration).

2.2. Mechanisms Facilitating Knowledge Flows

How do firms, embedded in relatively stable geographic and technological contexts, achieve the balance suggested above? We suggest that alliances and mobility are two distinct mechanisms that firms may employ to access contextually distant knowledge. To begin, we develop hypotheses regarding the two interfirm mechanisms independently from the context in which firms are embedded.

Alliances. A central idea in the literature on alliances is that they are useful mechanisms for knowledge acquisition and learning (Hamel et al. 1989). Empirical studies of alliance formation assume that search for new capabilities and strategic interdependencies within limited social contexts drive partner selection (e.g., Gulati 1995, Eisenhardt and Schoonhoven 1996). Powell et al. (1996) postulate the existence of "networks of learning," and suggest that participation in networks of R&D alliances facilitates the growth of new biotechnology firms, because these networks create access to knowledge.

In-depth case studies provide us with a rich illustration of learning between alliance or network partners at the expense of demonstrating overall knowledge flows across networks. Doz (1996) explores how alliances may be construed as learning processes, where learning occurs in multiple dimensions—environment, task, process, skill, and partner goals—and the amount of learning is facilitated or constrained by initial conditions. Dyer (1997) suggests that the breadth and intensity of the relationship between alliance partners will grow across time. Though there is considerable literature relating learning and alliances, few studies explicitly measure interfirm knowledge flows associated with alliances.

Once again, studies rooted in patent data have begun to explore this issue. In Stuart and Podolny's (1996) study of the major Japanese semiconductor firms, the authors suggest that Matsushita accomplished a technological transition through the strategic use of alliances. In two studies of alliances between multinational firms in 1985–1986, spanning a variety of industries, Mowery et al. (1996, 1998) demonstrate that certain alliances are followed by rises in the cross-citation and common-citation patterns between the firms, suggesting some transfer of knowledge.

HYPOTHESIS 3. *The likelihood that a focal firm will draw upon the knowledge stock of another increases with alliances between the pair of firms.*

Mobility. The notion that the mobility of people facilitates the flow of knowledge is hardly new. Several primarily descriptive studies suggest that people are an important conduit of interfirm knowledge transfer (Malecki 1991). However, most research suggests only a connection between mobility and knowledge flows, offering at best indirect evidence. For instance, Markusen et al. (1986) find that regions with high concentrations of technical workers attract new high-technology investment. In technology intensive industries as well, there are numerous descriptive studies of people carrying knowledge across firms (Hanson 1982). In the semiconductor industry, interviews with engineers reveal many anecdotes of interfirm knowledge flows associated with the mobility of engineers (Saxenian 1990, Rogers and Larsen 1984). In a study of the movement of top semiconductor managers across firms between 1976 and 1993, Boeker (1997) found that the prior organizational expertise of managers had an impact on product entry decisions of the new firm.

As was the case for alliance research, the most direct evidence linking mobility of engineers to interfirm knowledge flows may be accomplished through patent records. Almeida and Kogut (1999) show that after a semiconductor firm hired a new engineer, there was a significantly greater tendency for the hiring firm to cite the prior patents of the newly employed engineer than would be expected given its technology profile. In addition, Song et al. (2001) demonstrate

that during the early stage of development of Korean semiconductor firms, the practice of bringing U.S.-educated and U.S.-employed nationals back home leads to similar patenting practices. Thus, we suggest that when inventors move from one firm to another, they carry knowledge from the prior employer to the new one.

HYPOTHESIS 4. *The likelihood that a focal firm will draw upon the knowledge stock of another increases when the focal firm hires inventors previously employed by the other firm.*

2.3. Using Mechanisms to Reach Beyond Context

While our first two hypotheses suggest that firms are limited by technological and geographic context in their search for knowledge, the next two hypotheses suggest that the formation of alliances and the hiring of inventors are useful mechanisms for acquiring knowledge. We now move to the central question of this paper: Are these mechanisms useful for the acquisition of knowledge from dissimilar contexts? In other words, can firms use the mechanisms to overcome the limitations of contextually oriented search?

Of course, as pointed out earlier, both alliances and mobility are interrelated with technological and geographic contexts. First, they are more prevalent within contexts. For example, Mowery et al. (1998) demonstrate that alliances are more likely among firms that have more prealliance technological overlap. In Stuart and Podolny's (1996) study, contextual similarity and alliances are intertwined, as 9 of their 10 Japanese firms maintain similar technological positions across time and alliances among the firms are plentiful.

Similarly, Almeida and Kogut (1997, 1999) show that intraregional mobility is much more likely than interregional mobility for both the founders of startup firms in the semiconductor industry and for key semiconductor engineers. In fact, their studies suggest that a key reason for knowledge localization is the local mobility of experts. This suggests a second point—not only are these mechanisms more prevalent within context, they also shape local learning within context.

But is technological or geographic similarity necessary for alliances or mobility to facilitate interfirm

knowledge flows? As we have noted, a few studies support the idea that mechanisms can bridge distant contexts (Song et al. (2001) on interregional mobility for Korean semiconductor firms; Stuart and Podolny's (1996) example of Matsushita moving to new technological areas through the use of alliances). Thus, while likeness in geography or technology may increase the prevalence of these mechanisms, a basic question remains: Does similarity enhance or detract from the extent to which these mechanisms facilitate knowledge flows?

Advantages of Context-Convergent Mechanisms.

There are several reasons why our mechanisms of interest may work more effectively within context. First, common culture, which is more likely within context, can help smooth the flow of knowledge through alliances and mobility and aid its interpretation. As Saxenian (1994) suggests, the work practices, culture, and even technical terminology are often peculiar to a region and vary dramatically across regions. Second, common context increases the likelihood of similarity between firms in terms of their practices and routines. Institutional theorists have suggested that firms faced with uncertainty look to other visible organizations for clues on how to organize and act (Haunschild and Miner 1997). The commonality of organizational routines, facilitated by proximity, makes for easier absorption and interpretation of knowledge gained through the mechanisms. Finally, common context can create an environment of trust between firms and individuals, thus, enhancing the utility of the mechanisms of knowledge flows. For instance, geographic similarity enables more face-to-face interaction that helps in the building of trust between individuals (Porter 1990). Similarly, the network literature suggests that social networks within regions facilitate repeated interactions and the development of trust, thus, enhancing local knowledge flows through alliances and mobility (Coleman 1990, Walker et al. 1997).

Advantages of Context-Divergent Mechanisms.

We argue here that alliances and mobility embody "rich modes" of knowledge flow, and therefore may facilitate the flow of knowledge even across contexts. As Daft and Lengel (1986) have suggested, rich media

allow wide ranging and deep interactions between individuals and, thus, permit the establishment of trust and development of common understanding—both critical for interfirm knowledge flow. Alliances offer a wide range of media for interfirm interactions (including face-to-face communications) often across a considerable period of time (Almeida et al. 2002). The mobility of individuals offers the opportunity not just for transfer of his or her expertise, but the interpretation of this knowledge in a new context. Studies on alliances suggest that firms increasingly focus on setting up organizational mechanisms to properly manage them and, thus, facilitate interfirm knowledge exchange (Inkpen and Crossan 1995). Thus, firms often treat alliances as extensions of their internal organization, and are capable of exploiting this learning mechanism even in the face of differing contexts. Because senior managers often negotiate alliances and recruit key experts, they receive top management attention, and the learning process associated with these mechanisms is less likely to suffer from any negative consequences of divergent contexts. Hence, we can expect rich mechanisms like alliances and mobility to be minimally affected by the downsides of knowledge transfer across divergent contexts.

More importantly, divergent contexts could present an advantage over convergent contexts. One can argue that the occurrence of alliances or mobility between firms in a similar context merely duplicates preexisting relationships and offers little added value to the firm. In other words, when a firm generates access to the knowledge of another firm through a mechanism within context, it is often already accessible by a host of other informal mechanisms that emerge in similar context. However, distant technological and geographic contexts may often offer access to new and unique knowledge. The network literature on efficiency suggests that nonredundant ties increase knowledge flows (Granovetter 1973, Burt 1992). Thus, the occurrence of alliances or mobility between firms in dissimilar contexts may create connections to novel contexts and access to nonredundant knowledge, so important to innovation through recombination.

Thus, we argue that the capacity of these rich mechanisms to overcome the difficulties associated with

knowledge transfer across dissimilar contexts, accompanied by the opportunities to access novel knowledge from more distant contexts, make the effects of alliances and mobility on interfirm knowledge flows higher in dissimilar contexts. In other words, alliances and mobility are mechanisms that enable firms to overcome biases for knowledge search within local contexts. Hence,

HYPOTHESIS 5. The likelihood that a focal firm will draw upon the knowledge stock of another firm through mobility increases when the firms are not geographically proximate.

HYPOTHESIS 6. The likelihood that a focal firm will draw upon the knowledge stock of another firm through alliancing increases when the firms are not geographically proximate.

HYPOTHESIS 7. The likelihood that a focal firm will draw upon the knowledge stock of another firm through mobility increases with technological distance.

HYPOTHESIS 8. The likelihood that a focal firm will draw upon the knowledge stock of another firm through alliancing increases with technological distance.

3. Methods

3.1. Patent Data

In this study, we use patent data and in a variety of ways to shed light on the knowledge acquisition patterns of semiconductor firms. Since the pioneering work of Schmookler (1966) and Scherer (1965), patent data¹ have been commonly used by researchers to illuminate the process of innovation and to evaluate its relationship to technological and economic development. Patent data have received so much attention because they are systematically compiled, have detailed information, and are continuously available across time. A patent document contains a host of information, including citations to other patents. The

list of citations for each patent is arrived at through a uniform and rigorous process applied by the patent examiner as a representative of the patent office. The patent applicant and his or her lawyer are obliged by law to specify in the application any and all of "the prior art" of which he or she is aware. The list of patent citations so compiled is available on the patent document, along with information on the patenting firm, inventor, geographic location, and technology types. Thus, through patent documents, one can infer both organizational and technological antecedents to a particular invention and, thus, track knowledge flows across people, firms, geographic regions and countries, and time.

It would be inappropriate to claim that every patent citation represents knowledge flows, as some citations are introduced to distinguish the invention from dissimilar ones, or to protect the firm from litigation, while others are introduced by patent examiners. While acknowledging this noise in the citation process, we still believe that due to the rigorous and uniform process applied during citation compilation by the patent examiner (unlike the process for academic citations), as well as the widespread use of patenting in the semiconductor industry, patent citations allow us to observe the overall technological, geographic, and temporal patterns of knowledge flows, which can then be associated with the variety of underlying contexts and mechanisms.

In this paper, we use the detailed patent information available in a patent document to track interfirm knowledge flows through patent citations, and also to track interfirm mobility of semiconductor engineers, to measure technological overlaps between firms in the industry, and to geographically locate the innovative activities of these firms.

3.2. Selection and Classification of Firms

We examine our hypotheses in the context of the semiconductor industry. The semiconductor industry provides an ideal setting to investigate the innovation and knowledge acquisition patterns of firms. This industry is characterized by continuous innovation (Jelinek and Schoonhoven 1993) and the wide use of patents in this industry provides researchers with a systematic record of innovation, suggesting how

¹ A patent is the grant of a property right to an inventor for an invention conferred by the government. It establishes the "right to exclude others from making, using, or selling the invention" for a period of up to 17 years. A U.S. patent is granted for an invention which is "useful," "novel," and "nonobvious to a person of ordinary skill in the art" (U.S. Patent and Trademark Office 1992).

knowledge overlaps and flows between firms in this industry.

Many of the major technological advances were generated by startup firms (Braun and MacDonald 1982). Almeida and Kogut (1997) show that startup firms in the industry often investigate new technological territories while learning from other semiconductor firms. Research on the history of technological development of the semiconductor industry describes the phenomenon of entry by “waves” of startups at different points in time (Saxenian 1990). Our sample of firms for this study represents the wave of entrants into the industry between 1980 and 1989. Though these firms were located in different regions of the United States and abroad, had different years of founding, and focused on different semiconductor technologies, they can together be conceived as a cohort, imprinted by similar underlying technological and industrial conditions prevailing at their founding (Stinchcombe 1965). A cohort-based approach makes sense for our study, as our interest is in exploring how firms overcome contextual localization. Startups enter the industry with a more restricted technological range (Kim and Kogut 1996). At birth, these firms also tend to be rooted in their geographical area, with more cosmopolitan tendencies coming with time and growth (Almeida et al. 2003). Thus, this cohort, well recognized for its important role in spurring innovation (Kim and Kogut 1996), provides an ideal setting to examine whether and how firms transcend context.²

We obtained information for all firms founded between 1980 and 1989 that designed or fabricated semiconductor devices through databases from ICE and Dataquest, two private research firms specializing in semiconductor industry analysis. Because our purpose was to explore the mechanisms that allowed firms to exploit industry knowledge, we attempted to gather data for all firms that had been granted at least one semiconductor patent during the subsequent

1990–1995 period.³ Eighty-six firms were so identified. Twelve firms were ultimately dropped from this set due to missing information on size,⁴ geography, or technology. Therefore, our sample consisted of 74 firms.

Each of these focal firms could learn from many sources. We bound our analyses by exploring how the firms learn from other firms within the semiconductor industry. Thus, the possible sources of external knowledge for these firms include not only the other focal firms, but also firms founded before 1980. We term this earlier cohort of firms “incumbents” and identified 116 such firms. Thus, the unit of analysis we employ is the dyad—each of the variables of interest is a relationship variable between the receiver of knowledge (the focal firm) and the possible sources of innovative knowledge (the set of semiconductor firms, including both incumbents and focal firms).⁵

3.3. Variables

Our study design uses two windows. We predict knowledge flows from 1990–1995 as a function of context and mechanisms measured from 1980–1989. Descriptive statistics for our data are included in Table 1.

Knowledge Flows. For each of our focal firms, we catalogued all semiconductor patents granted to the firm between 1990 and 1995.⁶ The 74 firms in our

² Using a limited sample of patents, we compared citation behavior of firms belonging to this cohort to firms founded before 1980 and found that the post-1980 cohort made more use of external knowledge. We leave full exploration of intercohort differences to future research.

³ Another key reason we restrict our sample to innovating (i.e., patenting) firms becomes obvious when we describe our operationalization of variables: All of our key variables except alliances must be derived from patent data. Thus, startups with no patents cannot be associated with independent variables for our analyses. The concern with this sort of sampling strategy is that any significant relationship of an independent variable with knowledge building may represent a necessary, but not sufficient, condition for the relationship.

⁴ Eight firms designated as startups by ICE or Dataquest were subunits of larger firms, and size data reflected the larger firm rather than the subunit.

⁵ The variables we collect may be thought of as rectangular matrices of information, including both the dyadic relationships between startups and the dyadic relationships between a startup and an incumbent. Incumbent-incumbent dyads are not included in the analysis. Thus, the total possible number of dyadic observations is 13,986 (74 startups multiplied by 190 total firms, less 74 for the diagonal of the startup block of the matrix).

⁶ We use the application date of the patent as the date of invention.

Table 1 Descriptive Statistics

Variable	Mean	Std. dev	Min	Max	Correlations									
					2	3	4	5	6	7	8	9	10	11
(1) Citation count	0.33	1.9	0	63	-0.12	0.045	0.070	0.14	0.033	0.086	0.20	0.19	0.30	0.034
(2) Technological distance	0.72	0.27	0	1.4	—	-0.020	-0.12	-0.045	-0.088	-0.11	-0.26	-0.19	-0.21	0.094
(3) Geographic similarity	0.32	0.47	0	1	—	—	0.045	0.049	0.016	0.026	-0.016	-0.017	0.10	-0.15
(4) Alliance	0.016	0.17	0	4	—	—	—	0.052	0.041	0.045	0.019	0.052	0.070	0.013
(5) Mobility	0.0087	0.15	0	6	—	—	—	—	0.0040	0.020	0.042	0.069	0.094	-0.0040
(6) Age	6.0	2.3	1	10	—	—	—	—	—	0.45	0.10	-0.0008	-0.0009	0.036
(7) Log (size)	4.4	1.3	1.1	7.7	—	—	—	—	—	—	0.33	-0.0009	-0.0014	0.18
(8) Log (citer's recent patents)	2.0	1.1	0	5.1	—	—	—	—	—	—	—	-0.0011	-0.0012	0.16
(9) Log (citee's earlier patents)	3.1	2.9	0	9.2	—	—	—	—	—	—	—	—	0.72	0.0005
(10) Log (citee's recent citations received)	1.7	1.7	0	5.9	—	—	—	—	—	—	—	—	—	0.0007
(11) Headquarters outside United States	0.12	0.33	0	1	—	—	—	—	—	—	—	—	—	—

Note. $n = 13,986$.

sample had a total of 992 patents during this period—an average of more than 13 patents per firm. For each patent included in the sample, we tabulated the citations made to other patents, and linked those cited patents to the firms that owned them. Thus, each citation is treated as one instance of the focal firm drawing upon the knowledge of the cited firm, whether that firm was another focal firm or an incumbent. Self-citations were excluded from this set, and citations made to nonsemiconductor firms are not included in our sample. A total of 4,560 citations (on average, more than 61 per focal firm) between 1,200 dyads were identified.

Mobility. Our aim was to identify the instances when an inventor moved to any of our focal firms from any other focal firm or incumbent in our overall set of firms, thus facilitating interfirm transmission of knowledge from their earlier employers to the focal firms. To track mobility, we examined the set of semiconductor patents for each firm in our sample for the full 1980–1995 period. We then tracked each inventor listed on these patents through the 1980–1995 period, looking for instances where an inventor was employed by more than one firm. For example, if one inventor was listed on patents for Firm A in 1987, Firm B (a focal firm) in 1989, and Firm C (also a focal firm) in 1993, we determined that Firm C had access

to the knowledge of both Firms B and A, while Firm B had access to the knowledge of Firm A. Because we only wanted to tabulate mobility occurring between 1980 and 1989, we interpolated dates to the nearest month to estimate this timing. By this interpolation, the mobility between Firms B and C above would be estimated to occur in 1991, too late for our count, and would not be included. One hundred and twenty-one instances of mobility were identified.

Use of inventors' patent trajectories limits our ability to identify mobility in two ways. First, if a scientist moves from one firm (the source) to another (the recipient) and only patents at the recipient, we cannot record mobility. Errors of this type make our tests for mobility more conservative. In contrast, we also cannot record mobility when a mobile scientist only patents at the source firm, which might lead us to overestimate the effect of mobility. Because there are no comprehensive databases that track interfirm mobility during our study period, we are unable to avoid these types of errors.⁷

⁷ Investigation of sources through 10 semiconductor firms, 3 venture capital firms, data collection firms, industry associations, the U.S. Department of Labor, Bureau of Labor Statistics, the National Science Foundation, and several researchers who have studied the semiconductor industry in detail yielded no additional means to fortify the data.

To assess the severity of any bias that might lead us to overestimate results, we simulated additional random instances of mobility. In essence, we assessed whether our results would remain robust even if our method of identifying mobile engineers had captured just a small portion of the actual instances of mobility. The simulated mobility data were not correlated with citations or any of the independent variables, and no instances of citation were added. Thus, we are making a conservative assumption that the simulated mobility was purely noise. We generated various levels of simulated mobility, including 50% (meaning we simulated one mobility event for each actual event), 80% (four simulated to one actual event), and 90% (nine simulated to one actual).

Alliances. We compiled the announcements of every alliance formed between firms in our sample between 1980 and 1989 listed in the weekly publication *Electronic News*.⁸ We recorded the complete range of alliances that firms undertook, including joint ventures (for design or for fabrication), equity arrangements, marketing, design, fabrication, and extended licensing agreements.⁹ If an alliance was reported as being between three firms, to accommodate our data structure, we coded that alliance as three dyadic alliances, one between each pair of firms. No alliances among groups larger than three were reported for our sample firms. A total of 160 alliances were identified.

Technological Similarity. To capture the extent of technological overlap, we created a measure of technological distance between firm pairs during the 1980–1989 period. For each firm in our sample, we collected its semiconductor patents between

1980–1989. If the firm had more than 10 patents, 10 of the set were randomly selected. If the firm had less than three patents during this period, we used the earliest possible patent data after 1989. For each patent, we tabulated the technological classes to which the patent was assigned. Aggregating the set of patents for each firm, we summarized the percentage of assignments in each patent class. We then calculated the Euclidean distances between these patent class vectors for each pair of firms. This distance measure ranged from a low of zero (firms with identical patenting profiles) to a high of 1.4 (the square root of two, where both firms allocate 100% of their activity to one class, and each firm is active in a different class).¹⁰ In our analyses, therefore, we observe the effects of technological distance, where higher values of distance connote lower similarity. We also observe that when we split our sample at the mean value of technological similarity, alliances are more than twice as likely for dyads with high technological similarity, while mobility is more than five times as likely for dyads of the same type.

Other studies have used alternative measures of technological similarity derived from patent data. Stuart and Podolny (1996) and Mowery et al. (1996) have used common citation measures, where technological similarity increases with the degree to which two firms cite the same patents. Additionally, Mowery et al. (1996) also use cross-citation measures, where technological similarity increases with the degree to which two firms cite each other's patents. Because our dependent variable reflects citation of one firm by another, we avoid these types of measures for technological similarity. Our measure, derived from patent class data rather than citation

⁸ *Electronic News* is a weekly publication with extensive coverage of events in the electronics industry. A detailed search was made of more than 520 issues of the publication and every announcement of a semiconductor alliance was collected.

⁹ Our decision to record all types of alliances reflects our belief that any contractual agreement yields the potential for knowledge building. Because some studies of knowledge movement exclusively focus on technology alliances (i.e., R&D, technology development, joint venture for design, joint development, design), we also tabulated a count of alliances of this type. Approximately 10% of our original alliance count (licensing, marketing, manufacturing, and supply agreements) was excluded via this method, but results were not substantively different.

¹⁰ One might be concerned that certain patent classes never cite other patent classes, and firms that limit their activity to these classes are effectively not at risk of citing each other. Fortunately, this is not a significant issue in the semiconductor venue. In our data, 33 patent classes were included. While each patent is only associated with its primary class affiliation, the portfolios of patents for each firm were spread across multiple patent classes (only four startups had all patents in one class). Additionally, patenting in any particular technological class does not overly circumscribe the citation behavior of a firm—approximately half of all citations from a given class are made to other patents within the same class, with the other half made to patents of other classes.

data, follows in a long tradition of studies initiated by Jaffe (1986, 1989) and pursued by several scholars in economics and strategy since. Using the patent class-derived measure of technological similarity allows us to keep the technological similarity and knowledge flow variables conceptually and empirically separate. Indeed, the correlation between technological distance and knowledge-building in our data is only -0.12 .

Geographic Similarity. To control for various regional mechanisms that might enable interfirm knowledge flows, we created a binary variable to indicate whether these firms were located in the same geographic region. Regions were defined as states within the United States and countries outside the United States with two exceptions. We split California into northern and southern California, and combined New York, New Jersey, Connecticut, and Pennsylvania into one region. The regions where any firm was located were obtained from our sample of patents by consulting the inventor's location listed on the patent (for both the citing patent and the cited patent). By using this method, we could determine whether the inventors of each patent belonged to the same region or different regions at the time of patenting. If the inventors for a pair of firms were in the same region, the geographic similarity was set to one, otherwise zero. Thirty-two percent of our dyads were designated as geographically similar. Alliances and mobility were more common for geographically similar dyads by approximately the same ratios as they were for technologically similar dyads.

Controls. Several variables that might be correlated with the firm's ability to absorb knowledge were included as controls. Firm age was calculated as the number of years since the focal firm's founding as of 1990. Firm size was represented by the number of employees reported by the focal firm as of 1990. We also controlled for the number of semiconductor patents the focal firm had received during the 1990–1995 period, which would be empirically associated with the firm's propensity to cite (i.e., the more patents, the more citations) but also theoretically associated with the firm's absorptive capacity (i.e., the more knowledge stock, the more knowledge assimilation). Similarly, we controlled for the number of semiconductor patents the cited firm had received during

the 1980–1989 period because that should be empirically associated with the likelihood of the firm receiving citations. We also controlled for the cited firm's "citability": The total number of citations that the firm's semiconductor patents had received from the focal firms in our sample. This provides a base expectation for how much any one firm might be cited and, therefore, acts as an important control for firms owning patents that have become common knowledge.¹¹ Control variables with high skew (size, patent counts, and citation counts) were logged. Finally, to control for different patenting practices outside the United States, we included a dummy variable valued one when the focal firm's headquarters are located outside the United States.

3.4. Analyses

Because our dependent variable is a count with overdispersion, negative binomial regression is indicated (Hausman et al. 1984). Several models are explored. Our first model includes the controls and contextual variables, and our next model introduces the mechanisms to demonstrate their effects. Subsequent models introduce interactions between mechanisms and context. Because the four interactions represent assorted combinations of the same mechanisms and context variables, we enter each independently and retain those with significance to ensure that multicollinearity does not bias our estimates.

4. Results and Discussion

4.1. Findings

Table 2 demonstrates that results of negative binomial regression of the independent variables on the likelihood of knowledge flows to the focal firm are generally consistent with our hypotheses.¹² In Model 1, we

¹¹ Not surprisingly, this variable was strongly correlated with the cited firm's earlier stock of patents. We include this control to capture the effect of a firm's owning a well-known patent, i.e., one that generates far more citations than average. We also ran regressions without the correlated (stock of earlier patents) variable and results were robust.

¹² A binary formulation of the dependent variable examined via logistic regression yielded comparable results, and is not reported here for the sake of brevity.

Table 2 Negative Binomial Estimates for Knowledge Building

Variable	1	2	3	4	5	6	7
Technological distance	−1.6***	−1.6***	−1.6***	−1.6***	−1.7***	−1.7***	−1.7***
Geographic similarity	0.37***	0.34***	0.34***	0.33***	0.34***	0.33***	0.33***
Alliance		0.13	0.12	−0.0011	0.015	−1.1***	−0.80*
Mobility		0.36***	0.11	0.34***	−1.1***	0.29***	−0.89**
Age	−0.054***	−0.056***	−0.056***	−0.056***	−0.056***	−0.058***	−0.058***
Log (size)	0.072**	0.075**	0.076**	0.076**	0.080**	0.082**	0.083**
Log (citee's recent patents)	1.1***	1.1***	1.1***	1.1***	1.1***	1.1***	1.1***
Log (citee's earlier patents)	0.031**	0.030**	0.030**	0.030**	0.030**	0.030**	0.030**
Log (citee's recent citations received)	1.1***	1.1***	1.1***	1.1***	1.1***	1.1***	1.1***
Headquarters outside United States	−0.30***	−0.31***	−0.31***	−0.32***	−0.35***	−0.34***	−0.36***
Mobility * geographic similarity			0.31				
Alliance * geographic similarity				0.21			
Mobility * technological distance					2.9***		2.4***
Alliance * technological distance						2.2***	1.5***
Constant	−6.9***	−6.9***	−6.9***	−6.9***	−6.9***	−6.9***	−6.9***
Alpha	2.4***	2.4***	2.4***	2.4***	2.3***	2.4***	2.3***
Log likelihood	−4,678.8	−4,672.4	−4,671.9	−4,672.0	−4,664.9	−4,667.1	−4,663.0

Note. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. $n = 13,986$ and number of events = 4,560.

observe the effects of the contextual variables on interfirm knowledge flows, suggesting that technological distance has a significant negative effect on the dependent variable and geographic proximity obtains a significant positive effect. Taken together, these results support Hypotheses 1 and 2, portraying both technological and geographic localization of knowledge.

Model 2 explores the effects of the mechanisms on interfirm knowledge flows while retaining the contextual variables as controls. Here, we observe that mobility, as hypothesized, obtains a significant positive effect, but alliance does not obtain a significant effect. The addition of the two variables to the model improves the overall fit of the model (chi squared = 11.8; $p < 0.01$), demonstrating the effect of mobility over and above the contextual variables, supporting Hypothesis 4.

Models 3–6 separately introduce each of the context-mechanism interactions. The interactions of the mechanisms with geographic distance do not yield significant results. We cannot demonstrate that the mechanisms of alliances and mobility are more effective across geographic context, so Hypotheses 5 and 6 are not supported. Geography does not influ-

ence the effectiveness of mobility—apparently, mobility can yield knowledge building in distant and similar contexts. In contrast, the interactions of the mechanisms with technological distance both yield significant positive results, and these interactions also improve the overall fit of the model ($p < 0.01$). Apparently, the effects of alliances and mobility increase with technological distance, as predicted by Hypotheses 7 and 8. Simultaneous inclusion of both technological context interaction terms in Model 7 yields a robust result.

Note also that the control variables yield consistent results throughout all models. As expected, the number of patents by the focal firm, the number of patents by the cited firm, and the citability of the cited firm are all positive and significant throughout. Age is negatively associated with knowledge flows, while size is positively associated with knowledge flows. Firms with headquarters outside the United States draw less on the knowledge stock of other firms.

Finally, we turn to our simulated mobility data to assess the robustness of our results. These results are presented in Table 3. Two scenarios are presented: 80% simulated mobility (or four simulated instances of

Table 3 Negative Binomial Estimates For Knowledge Building with Simulated Mobility Data

Variable	80% Mobility simulated			90% Mobility simulated		
	Compare to actual model			Compare to actual model		
	(2)	(5)	(7)	(2)	(5)	(7)
	8	9	10	11	12	13
Technological distance	−1.6***	−1.7***	−1.7***	−1.6***	−1.7***	−1.7***
Geographic similarity	0.35***	0.36***	0.34***	0.36***	0.36***	0.35***
Alliance	0.16	0.10	−1.0***	0.17	0.14	−1.1***
Mobility	0.21**	−0.57**	−0.38	0.14*	−0.29	−0.12
Age	−0.056***	−0.058***	−0.060***	−0.056***	−0.057***	−0.059***
Log (size)	0.075**	0.078**	0.083**	0.074**	0.075**	0.081**
Log (citee's recent patents)	1.1***	1.1***	1.1***	1.1***	1.1***	1.1***
Log (citee's earlier patents)	0.030**	0.030**	0.031**	0.031**	0.031**	0.031**
Log (citee's recent citations received)	1.1***	1.1***	1.1***	1.1***	1.1***	1.1***
Headquarters outside United States	−0.30***	−0.32***	−0.34***	−0.30***	−0.31***	−0.34***
Mobility * technological distance		1.5***	1.1**		0.79*	0.45
Alliance * technological distance			2.0***			2.2***
Constant	−6.9***	−6.9***	−6.9***	−6.9***	−6.9***	−6.9***
Alpha	2.4***	2.4***	2.4***	2.4***	2.4***	2.4***
Log likelihood	−4,674.6	−4,670.8	−4,667.0	−4,676.0	−4,674.6	−4,669.5

Note. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. $n = 13,986$ and number of events = 4,560.

mobility for each actual event) and 90% simulated mobility (or nine simulated instances of mobility for each actual event). For each scenario, Table 3 displays the simulated analogues of the models that contain the main effect of mobility (originally Model 2, now seen in Models 8 and 11), the interaction of mobility and technological distance (originally Model 5, now seen in Models 9 and 12), and the full model with both significant interactions (originally Model 7, now seen in Models 10 and 13).¹³ With 80% simulated mobility, we observe that the main effect of mobility (Model 8) is still positive and significant, although the magnitude of the coefficient has decreased as would be expected. Models 9 and 10 demonstrate that the interaction of simulated mobility with technological distance also continues to yield significant positive effects ($p < 0.05$). Turning to 90% simulated mobility, we begin to observe the limits of our estimates. Significant effects are no longer observed in the full model,

and even the partial models only yield weak evidence of the same effects ($p < 0.10$). This simulation evidence suggests that any potential bias caused by missing instances of mobility is unlikely to have created an effect where one did not exist unless we had missed 9 out of every 10 instances of mobility among our inventors.

4.2. Extensions

Our results support the contention that knowledge is localized or contained within both technological and geographic contexts. Given this contextual localization of knowledge, our interest was in uncovering whether and when mechanisms like alliances and mobility would enable firms to reach beyond their local contexts, effectively filling in the holes in their contextual landscapes. Controlling for contextual localization of knowledge, we found support for the idea that mobility of inventors facilitates interfirm knowledge flows. Alliances, however, did not demonstrate the same overarching tendency. Thus, while our theory predicted that both mechanisms would have the same generic effect, our results indicate the

¹³ Analogous to our results for the actual mobility data, we found no significant coefficients for the interactions of geographic similarity with mechanisms and, therefore, do not include them in the full model.

value of considering distinctions between the two mechanisms.

Mobility is an individual-level phenomenon, while an alliance is an organization-level phenomenon. Mobility is a one-time transplant of a particular engineer's skill set, knowledge, and productive effort from one firm to another, with no residual coordination required between the firms. Thus, our lack of support for interaction between mobility and geographic context suggests that the knowledge flows associated with mobility obtain regardless of whether the inventor moves within or between regions. Alliances, in contrast, permit and often encourage ongoing interaction between partners, encompassing several levels of expertise and continuing over extended periods of time. While alliances so construed may represent more formal and broader vehicles for knowledge transfer, they may not always be used as vehicles for knowledge acquisition. Indeed, Mowery et al. (1996) suggest that alliances between firms can foster either convergence or divergence in knowledge bases; complementary specialization may be a strategic decision that mitigates the need for partners to learn from each other. Additionally, our alliance construct covers a wide range of contracts. When we restricted our alliance definition to exclude arms-length transactions, we were unable to distinguish significant differences in knowledge flows, but we are hopeful that future research will make headway in untangling how relational intensity and strategic decisions about knowledge specialization encourage and constrain knowledge flows.

We also did not explore the primary differences between our two contextual variables as we developed our hypotheses. It is important to note that geographical context is more static while technological context is more dynamic. Regions remain regions across time; firms can only change their geographic similarity profiles through changes in locations and, subsequently, embedding themselves in regional networks. This contrasts starkly with technological domains, where the very act of drawing on distant technological knowledge reduces technological distance between the two areas (cf. Podolny and Stuart 1995). Longitudinal approaches that allow for the dynamics of technological evolution will enrich

our understanding of the effects of technological context.

Our interaction results demonstrated that the effects of alliances and mobility on knowledge flows increased with technological distance. Conversely, this suggests that the more technologically similar a pair of firms, the less likely they are to draw on the others' knowledge stock after alliances or mobility. In the case of alliances, this may be true because high technological similarity facilitates complementary specialization. In the case of mobility, it may be that inventors and their employers are particularly careful about patenting behaviors that might fuel litigation regarding nondisclosure agreements. Clearly, when employees move to firms with similar technology orientations, this caution should be particularly acute.

Our simultaneous modeling of multiple mechanisms and contexts highlights the reality that firms have numerous formal and informal channels by which they may access knowledge. Though this paper suggests that alliances and mobility can both be used to extend technological and geographic reach, speculation on the differential uses of these mechanisms offers tantalizing possibilities for future research. For instance, Song et al. (2001) indicate that Korean semiconductor firms employ more complex learning mechanisms as they grow more technologically proficient, while Rosenkopf et al. (2001) show that informal interaction in technical committees serves to seed future formalized collaborations in the cellular industry. Future work must explore the relationships among the dependent and independent variables and strategic choice in the use of these mechanisms in more detail.

Our study joins the renewed emphasis on "small worlds" in network theory (Watts 1999, Kogut and Walker 2001) by demonstrating the effectiveness of mobility and alliances for accessing knowledge in distant contexts. It raises the question of whether distant search, while less prevalent, may actually be more effective than local search. While we demonstrate that the mechanisms of alliances and mobility may be employed to access knowledge in distant contexts, we do not suggest that the mechanisms should be primarily employed in divergent contexts. We simply

suggest that every firm is embedded in a context that has limits in terms of the breadth of knowledge possessed. The choice of whether and when to employ these mechanisms to distant contexts is a strategic choice left to managers. Research that more specifically focuses on the types of knowledge that may be accessed via these mechanisms will be of great benefit; incorporating notions of the variance of knowledge accessed and the speed of knowledge flows can help link studies like ours to the domain of organization learning and complement the work we have done here.

4.3. Limitations

Several limitations of our study must be acknowledged. First, our reliance on patent data for many of our measures limits our focus to the flows of knowledge that are codified in patents. While it may be reasonable to assume that flows of tacit knowledge also follow similar patterns (i.e., contextual localization with mechanisms facilitating flows between distant contexts), our data cannot demonstrate this assumption. Another issue that is an ongoing point of contention in studies of knowledge flows and patent data is the interpretation of patent citations as representing knowledge flows. Other studies have interpreted patent citations as representing technological similarity (Mowery et al. 1996) or strategic positioning with regard to patent litigation (Ziedonis 2002). Future research should incorporate methods that can also uncover knowledge flows outside the patent system.

One of the strengths of our paper—the ability to simultaneously compare the effects of multiple contexts and mechanisms on knowledge flows—also carries a limitation. Previous studies of the effects of alliances (Mowery et al. 1996, 1998) and mobility (Almeida and Kogut 1999) used matched-pairs analyses to convincingly demonstrate the effects of these mechanisms. To simultaneously evaluate all contexts and mechanisms, we relied on regression analyses of all startups in the industry. Fortunately, our methods generate comparable findings for the main effects of alliances and mobility. Specifically, we concur with Almeida and Kogut's (1999) findings on the role of mobility within regions, and also demonstrate mobility's effect across regions. With regard to alliances, we

view our lack of a main effect as consistent with the Mowery et al. (1996) findings that alliances may lead to either convergence or divergence of the knowledge base.

Our use of a cross-sectional pre-post design, where contexts and mechanisms during the 1980–1989 period were postulated to lead to citations during the 1990–1995 period, enabled us to construct our data set in a timely fashion. It raises the possibility, however, of reverse causality influencing the results. Specifically, one might argue that alliances and/or mobility would lead firms to become more technologically similar. Indeed, if Firm A were to have cited Firm B prior to an alliance or mobility event during 1980–1989, it is possible that we would impute subsequent citation to our mechanisms rather than to some other source of awareness. The pre-post design does not allow us to distinguish whether citations during the 1980–1989 period occurred before or after mobility events, and the imputation of the actual mobility date compounds this problem. In a random selection of five startups, we were only able to uncover one potential instance of this problem, so we assume that it is not prevalent in our data. That said, future research should attempt to utilize fully developed longitudinal databases to explore all possible temporal and causal links.

Finally, one needs to consider the generalizability of our results. We restricted our study to the cohort of innovative semiconductor firms (firms with at least one patent) founded during the 1980–1989 period. Semiconductor startups have traditionally played an important role in developing new technological fields. Many of the major design breakthroughs in the semiconductor industry were carried out in startup firms, while large firms have tended to dominate innovation in more established fields (Almeida and Kogut 1997). Future work should examine whether these findings persist for older firms as they age, and whether these findings replicate for the next cohort of entrants. In addition, our focus on the semiconductor industry as representative of a knowledge-based industry can be examined through study of other knowledge-based industries, such as biotechnology; and may also be enriched by studies of less knowledge-based industries to determine critical contingencies.

5. Conclusion

The second wave of entrants in the semiconductor industry has played a critical role in innovation and technology development, and this study sheds some light on the mechanisms they used to acquire knowledge. Through the use of patent data, we were able to systematically explore patterns of interfirm knowledge flows for this cohort. In contrast to most previous studies that examined only subsets of our mechanisms and contexts and their relationships to knowledge acquisition, our simultaneous consideration of multiple mechanisms and multiple contexts allowed us to demonstrate several findings. While we observed the pervasive bias toward geographically and technologically local search, we also found that mobility facilitated the flow of knowledge obtained regardless of context. Further, the effectiveness of alliances and mobility increased with technological distance. Our findings suggest that the managers have some discretion in considering how mechanisms may be deployed to reach out for new knowledge and, thus, fill in the gaps of their existing context.

Acknowledgments

Both authors equally contributed to this paper. The authors appreciate the suggestions of Rob Grant, Mauro Guillen, Connie Helfat, Trudy Heller, Jeho Lee, Daniel Levinthal, Yiorgos Mylonadis, Richard Nelson, Elaine Romanelli, Myles Shaver, Brian Silverman, Gabriel Szulanski, Mike Tushman, and participants at Wharton's Emerging Technologies Research Seminar. They are grateful for the editorial guidance of Linda Argote, the associate editor, and reviewers, and acknowledge the research assistance of Gina Dokko, Christina Fang, Glenn Luk, Eileen McCarthy, Anjana Pandey, Narayan Raj, and Preetam Rao. Financial support for this project was provided by the Mack Center for Technological Innovation at The Wharton School.

References

- Allen, R. C. 1983. Collective invention. *J. Econom. Behavior Organ.* 4(1) 1–24.
- Almeida, P., B. Kogut. 1997. The exploration of technological diversity and the geographic localization of innovation. *Small Bus. Econom.* 9 21–31.
- , ———. 1999. The localization of knowledge and the mobility of engineers in regional networks. *Management Sci.* 45(7) 905–917.
- , G. Dokko, L. Rosenkopf. 2003. Startup size and the mechanisms of external learning: Increasing opportunity but declining usefulness? *Res. Policy* 23(2) 301–315.
- , J. Song, R. Grant. 2002. Are firms superior to markets and alliances? An empirical test of cross-border knowledge building. *Organ. Sci.* 13(2) 147–161.
- Baum, J., S. X. Li, J. Usher. 2000. Making the next move: How experiential and vicarious learning shape the locations of chains' acquisition. *Admin. Sci. Quart.* 45 766–801.
- Boeker, W. 1997. Executive migration and strategic change: The effect of top manager movement on product entry. *Admin. Sci. Quart.* 42(2) 213–236.
- Braun, E., S. MacDonald. 1982. *Revolution in Miniature*, 2nd ed. Cambridge University Press, New York.
- Burt, R. 1992. *Structural Holes: The Social Structure of Competition*. Harvard University Press, Cambridge, MA.
- Cohen, W., D. Levinthal. 1990. Absorptive capacity: A new perspective on learning and innovation. *Admin. Sci. Quart.* 35 128–152.
- Coleman, J. 1990. *Foundations of Social Theory*. Harvard University Press, Cambridge, MA.
- Cyert, R., J. March. 1963. *A Behavioral Theory of the Firm*. Prentice-Hall, Englewood Cliffs, NJ.
- Daft, R. L., R. Lengel. 1986. Organizational information requirements, media richness and structural design. *Management Sci.* 32 554–571.
- Dosi, G. 1988. *Technical Change and Economic Theory*. Pinter Publishers, New York.
- Doz, Y. 1996. The evolution of cooperation in strategic alliances: Initial conditions or learning processes? *Strategic Management J.* 17(Special Issue) 55–83.
- Dyer, J. 1997. Effective interfirm collaboration: How transactors minimize transaction costs and maximize transaction value. *Strategic Management J.* 18(2) 535–556.
- Eisenhardt, K., C. Schoonhoven. 1996. Resource-based view of strategic alliance formation: Strategic and social effects in entrepreneurial firms. *Organ. Sci.* 7 136–150.
- Fleming, L. 2001. Recombinant uncertainty in technological search. *Management Sci.* 47(1) 117–132.
- Granovetter, M. 1973. The strength of weak ties. *Amer. J. Sociology* 78 1360–1380.
- Gulati, R. 1995. Social structure and alliance formation patterns: A longitudinal analysis. *Admin. Sci. Quart.* 40 619–652.
- Hamel, G., Y. Doz, C. K. Prahalad. 1989. Collaborate with your competitors and win. *Harvard Bus. Rev.* (Jan–Feb) 133–139.
- Hanson, D. 1982. *The New Alchemists: Silicon Valley and the Microelectronics Revolution*. Little, Brown and Company, Boston, MA.
- Haunschild P., A. Miner. 1997. Modes of interorganizational imitation: The effects of outcome salience and uncertainty. *Admin. Sci. Quart.* 42(3) 472–500.
- Hausman, J., B. Hall, Z. Griliches. 1984. Econometric models for count data with an application to the patents—R&D relationship. *Econometrica* 52 909–938.
- Helfat, C. 1994. Evolutionary trajectories in petroleum firm R&D. *Management Sci.* 40(12) 1720–1747.
- Herrigel, G. 1993. Large firms, small firms, and the governance of flexible specialization: The case of Baden Wuttemberg and socialized risk. Bruce Kogut, ed. *Country Competitiveness*. Oxford University Press, New York.

- Inkpen, A., M. Crossan. 1995. Believing is seeing: Joint ventures and organization learning. *J. Management Stud.* 32(5) 595–618.
- Jaffe, A. 1986. Technological opportunity and spillovers of R&D: Evidence from firms' patents, profits, and market value. *Amer. Econom. Rev.* 76 984–1001.
- . 1989. Characterizing the "technological position" of firms, with application to quantifying technological opportunity and research spillovers. *Res. Policy* 18 87–97.
- , M. Trajtenberg, R. Henderson. 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. *Quart. J. Econom.* 108(3) 577–675.
- Jelinek, M., C. Schoonhoven. 1993. *The Innovation Marathon*. Jossey-Bass Publishers, San Francisco, CA.
- Kim, D.-J., B. Kogut. 1996. Technological platforms and diversification. *Organ. Sci.* 7(3) 283–301.
- Kogut, B., U. Zander. 1992. Knowledge of the firm, combinative capabilities, and the replication of technology. *Organ. Sci.* 3(3) 383–397.
- , G. Walker. 2001. The small world of Germany and the durability of national networks. *Amer. Sociological Rev.* 66(3) 317–335.
- Liebeskind, J. P., A. L. Oliver, L. Zucker, M. Brewer. 1996. Social networks, learning, and flexibility: Sourcing scientific knowledge in new biotechnology firms. *Organ. Sci.* 7(4) 428–443.
- Malecki, E. J. 1991. *Technology and Economic Development*. John Wiley and Sons, New York.
- March, J. G. 1991. Exploration and exploitation in organizational learning. *Organ. Sci.* 2(1) 71–87.
- , H. Simon. 1958. *Organizations*. John Wiley and Sons, New York.
- Markusen, A., P. Hall, A. Glasmeier. 1986. *High Tech America*. Allen and Unwin, Boston, MA.
- Martin, X., W. Mitchell. 1998. The influence of local search and performance heuristics on new design introduction in a new product market. *Res. Policy* 26(7) 753–771.
- Mowery, D., J. Oxley, B. Silverman. 1996. Strategic alliances and interfirm knowledge transfer. *Strategic Management J.* 17(Winter Special Issue) 77–92.
- , ———, ———. 1998. Technological overlap and interfirm cooperation: Implications for the resource-based view of the firm. *Res. Policy* 27(5) 507–523.
- Nelson, R., S. Winter. 1982. *An Evolutionary Theory of Economic Change*. Harvard University Press, Cambridge, MA.
- Piore, M., C. Sabel. 1984. *The Second Industrial Divide: Possibilities for Prosperity*. Basic Books, New York.
- Podolny, J., T. Stuart. 1995. A role-based ecology of technological change. *Amer. J. Sociology* 100(5) 1224–1260.
- Porter, M. E. 1990. *The Competitive Advantage of Nations*. Free Press, New York.
- Powell, W., K. Koput, L. Smith-Doerr. 1996. Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. *Admin. Sci. Quart.* 41 116–145.
- Rogers, E., J. Larsen. 1984. *Silicon Valley Fever*. Basic Books, New York.
- Rosenkopf, L., A. Nerkar. 2001. Beyond local search: Boundary-spanning, exploration and impact in the optical disc industry. *Strategic Management J.* 22 287–306.
- , M. L. Tushman. 1998. The coevolution of community networks and technology: Lessons from the flight simulation industry. *Indust. Corporate Change* 7 311–346.
- , A. Metiu, V. George. 2001. From the bottom up? Technical committee activity and alliance formation. *Admin. Sci. Quart.* 46 748–772.
- Saxenian, A. 1990. Regional networks and the resurgence of Silicon Valley. *California Management Rev.* 33(1) 89–112.
- . 1994. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Harvard University Press, Cambridge, MA.
- Scherer, F. M. 1965. Firm size, market structure, opportunity and the output of patented inventions. *Amer. Econom. Rev.* (December) 1097–1125.
- Schmookler, J. 1966. *Invention and Economic Growth*. Harvard University Press, Cambridge, MA.
- Song, J., P. Almeida, G. Wu. 2001. Mobility of engineers and cross-border knowledge building: The technological catching-up case of Korean and Taiwanese semiconductor firms. H. Chesbrough, R. Burgelman, eds. *Research in Technology and Innovation Management*. JAI Press, New York.
- Sorenson, J., T. Stuart. 2000. Aging, obsolescence and organizational innovation. *Admin. Sci. Quart.* 45 81–112.
- Stinchcombe, A. 1965. Social structure and organizations. J. G. March, ed. *Handbook of Organizations*. Rand McNally, Chicago, IL.
- Stuart, T., J. Podolny. 1996. Local search and the evolution of technological capabilities. *Strategic Management J.* 17 (Summer Special Issue) 21–38.
- U.S. Patent and Trademark Office. 1992. *General Information Concerning Patents*. U.S. Department of Commerce, Washington, DC.
- von Hippel, E. 1987. Cooperation between rivals: Informal know-how trading. *Res. Policy* 16 291–302.
- . 1988. *The Sources of Innovation*. Oxford University Press, New York.
- . 1994. "Sticky information" and the locus of problem solving: Implications for innovation. *Management Sci.* 40(4) 429.
- Walker, G., B. Kogut, W. Shan. 1997. Social capital, structural holes and the formation of an industry network. *Organ. Sci.* 8(2) 109–125.
- Watts, D. 1999. *Small Worlds*. Princeton University Press, Princeton, NJ.
- Ziedonis, R. 2002. Standing on the crowded shoulders of giants: Fragmented rights and incentives to patent. Working paper, University of Pennsylvania, Philadelphia, PA.

Accepted by Linda Argote, former department editor; received October 17, 1997. This paper was with the authors 3 years and 4 months for 3 revisions.