Does distance still matter? Geographic proximity and new product development

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ABSTRACT

Many firms rely on external organizations to acquire knowledge that is useful for developing creative new products and reducing the time needed to bring these products to market. Cluster theory suggests that this knowledge is often obtained from organizations located in close geographic proximity. Specifically, proximity is assumed to foster heightened face-to-face communication, strengthened relational ties, increased knowledge acquisition, and enhanced new product outcomes. The authors identify the limitations of these assumptions and offer an enriched model of the influence of geographic proximity on new product development, which they test using both a cross- sectional survey of 155 firms in the U.S. optics industry and a longitudinal follow-up survey of 73 of these firms. They find that firms located in close proximity engage in increased face-to-face communication, but this communication has little effect on the acquisition of the types of knowledge that lead to enhanced new product outcomes. In contrast, they find that e-mail communication leads to both enhanced new product creativity and development speed. In addition, they find that relational ties moderate rather than mediate the path connecting geographic proximity and new product outcomes. These findings imply that the new product development outcomes typically ascribed to close geographic proximity may actually be attributed to strong relational ties.

In the continual search for competitive advantage, finns try to develop innovative new products as quickly as possible. The importance of new product development for Iong-te1m competitive success is widely recognized by the marketing community (for a review, see Henna1t and Szy- manski 2001). In general, marketing has viewed the development of new products from the perspective of an isolated firm engaged in solo activity. Thus, the major thmst of extant new product development research has been on intemal processes, such as the f01mation and coordination of new product development teams (e.g., Olson, Walker, and Reuke1t 1995; Sarin and Mahajan 2001) and the role of organizational culture in new product development success (e.g., Deshpande, Farley, and Webster 1993; Mo01man 1995).

Because of the growth of global competition, rapid technological advances, and increasing demands from customers, many fi1ms realize that they need help from extemal organizations, such as customers, suppliers, and even competitors, to develop innovative and timely new products (Wind and Mahajan 1997). In response, an increasing number of marketing studies have begun to examine new product development alliances (Rindfleisch and Mo01man 2001, 2003; Sivadas and Dwyer 2000). However, research suggests that f01mal alliances represent only a small fraction of interorganizational influence on new product development because much of this influence comes in the form of inf01mal information sharing rather than f01mal agreements (Allen 1983; Von Hippe! 1987). To date, the marketing literature has little to contribute to the nature or the impact of this inf01mal inf01mation shruing on new product development activities.

Outside of mru·keting, however, the connection between informal interorganizational inf01mation sharing and new product development has received considerable attention from scholars who study industry clusters. These scholars argue that inf01mal inf01mation shruing is vital for new product development and that this sharing is facilitated by geographic proximity, which serves to enhance face-to-face communication and the development of strong relational ties (Gordon and McCann 2000; Porter 1998a, b; Sternberg 1999). As evidence for these claims, the cluster literature has generated many case studies that document the innovation-related benefits associated with such industry clusters as Silicon Valley (Saxenian 1994), the Formula 1 race car cluster near London (Henry and Pinch 2000), and the knitwear and clothing clusters in northern Italy (Rosenfeld 1997). Although these case studies suggest a wide range of benefits for firms located in such clusters, the evidence is mostly anecdotal and does not directly examine the process by which geographic proximity affects new product outcomes.

In this article, we offer a new conceptual model of how geographic proximity affects new product development out- comes. However, rather than taking cluster theory's assumed linkages at face value, we offer an enriched theoretical explanation that integrates cluster theory with research on electronic communication, interorganizational relationships, organizational learning, and new product development. This alternative model accounts for important subtleties that cluster theorists have not considered. For example, we question the widely held assumption that geo- graphic proximity leads to close relational ties (e.g., Porter 1998a, b). Similarly, our model recognizes that electronic communication may rival face-to-face contact as a means to acquire key knowledge. We test the proposed model through both a cross-sectional survey of 155 optics manufacturing firms and a longitudinal survey of 73 of these firms.

THE ROLE OF DISTANCE IN MARKETING AND BEW PRODUCT DEVELOPEMENT

The role of distance (or location) has a long history in the marketing literature and has been examined across a wide range of contexts, including marketing-mix decisions (e.g., Howard 1957), retail structure (e.g., Cox 1959; Ingene and Brown 1987), distribution channel design (e.g., Bucklin 1966), and manufacturing investment (e.g., Alderson and Green 1964; Greenhut 1956). In general, this earlier literature focused on spatial distribution of buyers and sellers and physical distribution costs. More recent marketing studies examine the role of geographic proximity in interfirm relations, finding that firms in close geographic proximity face lower costs (Cannon and Homburg 2001), display a weaker competitor focus (McEvily and Zaheer 1999), and draw on each other's knowledge base when developing new products (Rosenkopf and Almeida 2001). Thus, the marketing literature has shown an enduring interest in geographic location; however, it has given relatively little attention to the role of location in interorganizational new product development.

Geographic proximity has also been the subject of considerable inquiry among economists (e.g., Krugman 1991; Marshall 1920). For example, the concept of "agglomerative economies" argues that geographically concentrated firms in the same industry benefit from externalities, such as access to skilled labor, existing channels of distribution, and knowledge spillovers (e.g., Ciccone and Hall 1996; Goldstein and Gronberg 1984). This view has given rise to the concept of industry clusters (also known as "industrial districts") among scholars in economic geography, regional development, and business strategy (e.g., Porter 1990, 1998a, b; Rosenfeld 1997; Saxenian 1994; Sternberg 1991). According to Porter (1998b, p. 199), clusters are "a geo- graphically proximate group of interconnected companies and associated institutions in a particular field." An essential difference between the older concept of agglomerative economies and the newer study of industry clusters is the notion that in addition to enjoying a common set of externalities, the members of a cluster also share close relational ties (i.e., norms of trust and reciprocity) that foster knowledge exchange (Harrison 1992; Rosenfeld 1997). In contrast to new product alliances, cluster-based knowledge sharing largely reflects informal mechanisms rather than formalized cooperative arrangements (Enright 1991).

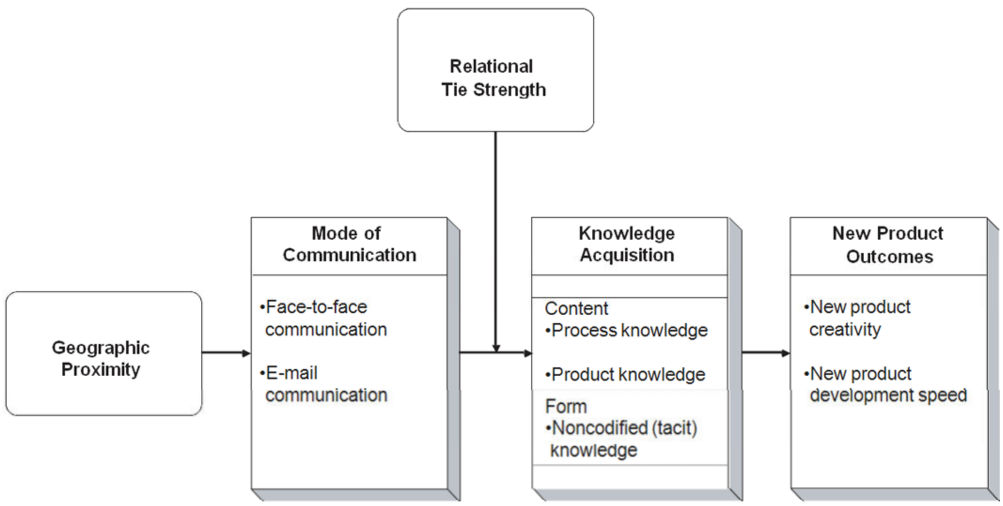
Cluster theorists argue that clusters represent a new way to view competitiveness and strategy in general (e.g., Porter 1990, 1998a, b). Specifically, cluster theory offers a novel, institutional perspective on marketing strategy by suggesting that individual firm-level outcomes are influenced by a manufacturer's location in a broader, geographically concentrated learning community. Thus, cluster theory points to the important role of external players, such as nearby suppliers, customers, competitors, and research institutes. A firm's relationships (both geographic and social) with these broader constituents are believed to play a key role in its learning ability, innovation outcomes, and ultimate success (Porter 1998a, b; Saxenian 1994). As a result, cluster theory emphasizes the importance of external agents in providing firms with the information and know-how necessary for innovative activities.

To date, cluster research concentrates on either developing theoretical treatises of the benefits of geographic proximity or demonstrating industry clusters in action through case studies of prominent clusters. In general, cluster advocates seem to suggest that geographic proximity provides an almost magical effect on new product innovation. The purported benefits of geographic proximity for new product development hinge on three critical but relatively untested assumptions: (1) proximity enhances face-to-face communication and the development of strong relational ties (e.g., Enright 1991; Rosenfeld 1997; Saxenian 1994), (2) face-to-face communication is the optimum way to acquire knowledge (e.g., Porter 1998b; Sternberg 1991), and (3) the most valuable knowledge comes in tacit (i.e., noncodified) form (e.g., Porter 1998b; Rosenfeld 1997). However, as we note in the following section, research on interorganizational relationships, electronic communication, organizational learning, and new product development indicates that each of these assumptions may be either inaccurate or incomplete. Our next section integrates the key findings from these other literature bases into cluster theory to develop an enriched model of how geographic proximity influences new product development.

CONCEPTUAL FRAMEWORK

In line with both cluster theory (e.g., Saxenian 1994; Stern- berg 1999) and research on new product development (e.g., Moorman 1995), our conceptualization of how geographic proximity influences new product development focuses on the acquisition and utilization of new product–related knowledge. We define this knowledge as "technical information directly relevant to new product development" (Rindfleisch and Moorman 2001, p. 4) and recognize that this knowledge has properties of both form and content. The remainder of this section elucidates the theoretical basis of our model and its hypothesized effects, which we graphically depict in Figure 1.

Figure 1
The effect of geographic proximity and relational ties on new product outcomes



Geographic proximity, communication and relational ties

The fundamental tenet of cluster theory is that close geo- graphic proximity enables frequent face-to-face contact with key knowledge providers, including suppliers, buyers, research institutes, alliance members, and even competitors (Audretsch 1998; Enright 1991; Rosenfeld 1997). For example, Sternberg (1991) describes how shared geo- graphic proximity among optics firms in Rochester, N.Y., enables them to engage in frequent face-to-face communication through such forums as local engineering association meetings. Likewise, Audretsch and Stephan (1996) suggest that close geographic proximity facilitates a firm's face-to- face contact with scientists from research institutes through participation in local workshops and seminars and through informal social interactions. This purported link is also sup- ported by research on interpersonal communication, which has found that physical proximity is positively related to greater amounts of face-to-face communication (Conrath 1973; Gullahorn 1952).

In addition to communicating face-to-face, cluster members can also communicate with one another through several alternative communication channels, such as telephone, fax, mail, e-mail, and electronic discussion groups. To date, the cluster literature is largely silent on the relationship between geographic proximity and these alternative modes of communication. Intuitively, there is no reason to expect that physical closeness should enhance these other forms of communication, because most of them have been developed to overcome physical distance (Audretsch and Stephan 1996). Indeed, because new product development personnel in organizations located further away (i.e., beyond a short driving distance) should have less opportunity to meet face-to-face, they may favor the increased usage of distance-spanning communication such as e-mail as a partial substitute for face-to-face meetings. However, the lack of prior research on this topic does not provide a solid basis to hypothesize that proximity will be either positively or negatively related to e-mail communication. Thus:

H_1: Geographic proximity is (a) positively related to the frequency of face-to-face communication but (b) unrelated to the frequency of e-mail communication.

Geographic proximity is also believed to help firms develop strong relational ties with their knowledge providers (Audretsch 1998; Harrison 1992; Henry and Pinch 2000; Porter 1998a). For example, Harrison (1992) notes that the repeated interaction (both planned and unplanned) afforded by close geographic proximity helps firms develop mutual trust. As Rosenfeld (1997, p. 20) suggests, "Trust is established through the kind of informal business and social exchanges that take place at barbecues and golf events, not videoconferences." This view is also echoed by sociologists, who argue that close physical proximity enhances the development of trust and reciprocity among community members (Etzioni and Etzioni 1999). Thus, close geographic proximity is assumed to enhance the formation of "strong ties" between knowledge providers and receivers (see Granovetter 1973).

Although geographic proximity may foster the development of strong ties among some cluster members, the generalizability of this relationship remains an open question. The literature does not provide empirical evidence of such a relationship. As Granovetter (1973) notes, strong ties take a considerable amount of time and effort to build and maintain. Thus, social communities are likely to be composed of a few strong ties and many weak ones. According to Van der Linde (2003), geographically concentrated industry clusters often consist of hundreds of firms. Thus, it seems untenable that a firm would develop strong relational ties with all the suppliers, buyers, competitors, and research institutes within close geographic proximity. Moreover, in the marketing relationship literature, geographic proximity is not a central component of any existing conceptualizations of relational norms, commitment, or trust (e.g., Ganesan 1994; Heide 1994; Moorman, Zaltman, and Deshpandé 1992). Therefore, we diverge from cluster theory by suggesting that relational closeness is not synonymous with or an automatic consequence of geographic proximity; we consider it an exogenous construct in our conceptual model.

Thus:

H_2:Geographic proximity is unrelated to relational tie strength with knowledge providers.

Communication, knowledge acquisition and relational ties

As we previously noted, cluster theorists emphasize the importance of interpersonal, face-to-face communication for knowledge acquisition. Our conceptual model attempts to enrich this view by adopting a broader perspective of both constructs. Specifically, as our first hypothesis suggests, e-mail communication is an important means of knowledge acquisition. Moreover, we recognize that knowledge has properties of both form and content. In this section, we specify the relationship between communication mode and knowledge type in greater detail, and we consider the moderating role of relational ties.

Communication and knowledge form. The cluster literature emphasizes tacit knowledge acquisition as a key out- come of face-to-face communication (Enright 1991; Porter 1998a, b; Rosenfeld 1997). However, tacit knowledge is inherently difficult to articulate (Polanyi 1966); it is difficult to codify in writing, tends to be hands-on and informal in nature, and is thus difficult to transfer to others (Stern- berg et al. 2000). Such noncodified knowledge is viewed as best delivered through individual, face-to-face contact in an apprentice-like manner. This view of tacit knowledge focuses on the form (i.e., codification in writing) of knowledge as a key property that affects its ease of transfer (Kogut and Zander 1992). Everyday examples of noncodified knowledge include such practical know-how as tying shoes or riding a bicycle. In an industrial context, noncodified knowledge often includes the embodied know-how of a skilled technician, which can be essential to the development of innovative routines to manufacture new products.

Given its embodied nature, knowledge in noncodified form is assumed to be best transmitted through the intimate, high-context, and hands-on setting of face-to-face interaction rather than through less personal, sensory-poor, distance-spanning communication vehicles, such as telephone conversations or e-mail messages (Baptista 2001; Zaheer and Manrakhan 2001). In addition to being intimate and informal, face-to-face communication is also considered richer and more capable of conveying more nuanced understandings because of its use of nonverbal cues and the ability to provide synchronous feedback (Daft and Lengel 1986). Thus, the rich modality of face-to-face communication should enhance noncodified knowledge acquisition (Porter 1998a, b; Sternberg 1991). Thus:

H_3:Face-to-face communication is more strongly related to noncodified knowledge acquisition than is e-mail communication.

Communication and knowledge content (product and process). Research on organizational learning suggests that in addition to form, content is another important aspect of knowledge. This literature distinguishes between product knowledge and process knowledge (Kogut and Zander 1992; Rindfleisch and Moorman 2001). Product knowledge encompasses facts, whereas process knowledge encompasses procedures (Kogut and Zander 1992; Zander and Kogut 1995). Because we expect that relational ties have a moderating influence on the effect of mode of interpersonal communication on the acquisition of each type of knowledge content, we do not offer a hypothesis about the direct effects between these constructs; instead, we focus on the more nuanced moderating role of relational ties.

The moderating role of relational ties. Although relational ties are unlikely to covary with geographic distance, we suggest that these ties are important in terms of the acquisition of knowledge content from knowledge providers. Specifically, we propose that relationship tie strength moderates the relationship between the communication mode and both product and process knowledge acquisition. This premise is based on findings from the strength-of-ties literature, which suggests that valuable knowledge is much more likely to be transmitted through strong ties than through weak ones. For example, Frenzen and Nakamoto (1993) show that consumers are significantly more willing to transmit knowledge about an important sale to a close friend than to a casual acquaintance. In an organizational context, Rindfleisch and Moorman (2001) find that tie strength is positively associated with knowledge acquisition in new product alliances.

Specifically, we propose that strong relational ties enhance the transfer of each type of knowledge content through its primary communication mode (i.e., face-to-face or e-mail). An important dimension of knowledge that affects its ease of transfer is complexity. Zander and Kogut (1995) argue that more complex knowledge (i.e., knowledge that involves a larger number of critical and interacting elements) is more difficult to communicate and transfer to another organization. According to this view, product- related knowledge tends to be relatively simple and straight- forward; thus, product knowledge should be highly amenable to e-mail communication. In contrast, knowledge about processes tends to be more complex; thus, it is more difficult to communicate, rendering it more amenable to face-to-face communication. Unlike e-mail, face-to-face communication affords the opportunity to explain highly detailed specifications, monitor a recipient's understanding, and clarify misunderstandings in real time. Strong relational ties should enhance the transfer of both types of knowledge because the closeness and mutual reciprocity that characterize such ties (e.g., Granovetter 1973) will enhance the ability and motivation of knowledge providers to better under- stand how best to convey and clarify both product and process knowledge. Thus:

H_{4a}: Relational tie strength moderates the effect of e-mail communication on product knowledge acquisition such that its acquisition is greater among firms with strong ties to their knowledge providers.

H_{4b}: Relational tie strength moderates the effect of face-to- face communication on process knowledge acquisition such that its acquisition is greater among firms with strong ties to their knowledge providers.

Knowledge acquisition and new product outcomes

As several new product development scholars note, knowledge is the foundation for new product innovation (Kotabe and Swan 1995; Madhavan and Grover 1998; Moorman and Miner 1998). Both the form and the content of this knowledge appear to be important inputs to successful new product development outcomes. For example, noncodified (tacit) knowledge is viewed as providing firms with the embodied know-how necessary to develop innovative products (Non- aka, Toyama, and Konno 2000). Conversely, product and process knowledge provide the important facts, specifications, and procedural details that enable a firm to control the innovation process (Nonaka and Takeuchi 1995).

For many firms, two of the most critical outcomes of new product development are (1) the creativity of new products and (2) the speed with which these products are developed (Griffin 1993; Moorman 1995). Although these outcomes are often positively related (Rindfleisch and Moorman 2001), they appear to have different antecedents in terms of knowledge inputs. Specifically, new product creativity is most often determined in the early stages of the product development process (Urban and Hauser 1980). Research indicates that the initial stages of idea generation and concept testing are highly reliant on the development or acquisition of novel concepts and findings (i.e., product knowledge) (Andrews and Smith 1996). In contrast, the speed of new product development is more highly dependent on later stages of the product development process (Urban and Hauser 1980). Research suggests that late-stage activities, such as prototype development and manufacturing design, rely heavily on the development or acquisition and application of efficient processes and procedures (i.e., process knowledge) (Millson, Raj, and Wilemon 1992).

An examination of the different knowledge needs of new product creativity and development speed suggests that creativity mostly depends on product knowledge acquisition, whereas speed mostly depends on process knowledge acquisition (Miner, Bassoff, and Moorman 2001; Rind- fleisch and Moorman 2001). Furthermore, noncodified knowledge appears to influence creativity and speed differently. Specifically, the informal, unstructured, and dynamic nature of tacit knowledge should enhance new product creativity (Cooke and Morgan 1998; Leamer and Storper 2001) but hamper the speed of new product development (Hansen 1999; Zander and Kogut 1995). Thus:

H5: New product creativity is more strongly influenced by product knowledge than by process knowledge.

H6: New product development speed is more strongly influenced by process knowledge than by product knowledge.

H7: (a) New product creativity is positively related to noncodified knowledge, whereas (b) new product development speed is negatively related to noncodified knowledge.

Organizational learning scholars often characterize the acquisition and utilization of knowledge as a dynamic process that unfolds over time (Moorman 1995; Nonaka, Toyama, and Konno 2000). To use acquired knowledge fully, organizations must engage in assimilation, sense-making, and dissemination activities. The dynamic nature of organizational learning is reflected in the concept of absorptive capacity, which posits that over time, firms can develop their ability to assimilate and apply knowledge effectively (Cohen and Levinthal 1990). Although absorptive capacity has traditionally been conceptualized as a by-product of internal research and development (R&D), recent research suggests that it can also be fostered by the acquisition of information from external knowledge providers (Scott 2003; Zahra and George 2002). Thus, in addition to enhancing short-term effects on new product outcomes by providing information that helps a firm solve an immediate new product development dilemma, product and process knowledge acquisition can also have a longer-term payoff for new product development by enhancing a firm's basic ability to develop new products in a more creative and timely manner.

Tacit knowledge is also a dynamic entity that can take considerable time to convey and acquire (Polanyi 1966). For example, in Germany, the making of optical instruments has been called the "technology of the golden hands," requiring specialized skills that are traditionally passed from an experienced craftsman to an apprentice over a period of several years (Enright 1991). Thus, cluster theory's assumed beneficial effects of tacit knowledge on new product development outcomes may occur over a lengthy period. Over time, the positive effects of acquiring noncodified knowledge on new product creativity should be enhanced, whereas its negative effects on new product development speed should be attenuated as the recipient firm acquires a deeper level of understanding and learns heuristic shortcuts to speed new products to market. Thus, we expect the following effects of knowledge acquisition (both content and form) on new product outcomes over time:

H8: The positive effect of acquiring product knowledge on new product creativity is strengthened over time.

H9: The positive effect of acquiring process knowledge on new product development speed is strengthened over time.

H10: (a) The positive effect of noncodified knowledge on new product creativity is strengthened over time, and (b) the negative effect of noncodified knowledge on new product development speed is weakened over time.

METHOD

Participants and procedures

We selected the U.S. optics industry as the context for our inquiry. This industry is particularly appropriate because optics manufacturers place considerable importance on knowledge acquisition and new product development (Committee on Optical Science and Engineering 1998). In addition, most U.S. optics firms and research institutions are located in a few geographically concentrated clusters (e.g., Boston, Boulder, Orlando, Rochester, Tucson).

Although all optical products share a common basis in the science of light and light transmission, the industry includes a diverse range of products and applications (e.g., fiber optics for telecommunications, imaging systems for medical and office equipment, lenses for microscopes and telescopes) and does not fall neatly into existing industry classification systems, such as Standard Industrial Classification codes. Therefore, we constructed our own database of optics manufacturers from membership directories of professional societies and regional industry associations. From these sources, we identified 655 U.S. optics firms for possible inclusion in our study.

In line with prior studies of new product development (e.g., Rindfleisch and Moorman 2001; Robertson and Gatignon 1998), we identified specific key informants (Campbell 1955), targeting vice presidents of R&D or people in similar high-level positions with intimate knowledge of their firms' new product development activities. Precontacting these people for verification eliminated 219 firms that were either not manufacturers or not engaged in any recent new product development or for which we were not able to identify a knowledgeable informant. This screening process yielded a sampling frame of 436 firms.

Initialsurvey. We mailed each firm a cover letter, an endorsement letter from the head of a leading university- based optical sciences center, a survey, a postage-paid reply envelope, and $5 as an incentive. Three weeks later, we sent a reminder postcard. We mailed a second set of survey materials (sans the $5) to firms that did not respond within six weeks. Twelve surveys were returned as undeliverable, and another 36 firms replied that they were not currently involved in any new product activities. This left a final sampling frame of 388 firms, 169 of which returned the survey (155 were usable), for an effective response rate of 44%. The response rate and sample size compare favorably with recent studies of new product development (e.g., Sivadas and Dwyer 2000). We received the 155 usable responses from firms in 25 states, including each of the eight U.S. optics clusters. Of the 155 responding firms, 124 (80%) were located in an optics cluster, and the rest were located in states without a large concentration of optics firms.

We assessed potential nonresponse bias through an extrapolation method that compared early respondents with late respondents (Armstrong and Overton 1977). We found no significant differences in means or variances for any key constructs between early (i.e., before the second mailing) and late (i.e., after the second mailing) respondents, suggesting that nonresponse bias was not a problem in this study. As a validity check, respondents reported that they were highly knowledgeable about (mean = 6.62 on a seven- point scale) and involved in (mean = 6.38 on a seven-point scale) the focal new product development project and had worked for their firm for an average of ten years. Seventy- one percent were chief executive officers, presidents, vice presidents, or directors, and most respondents (72%) had advanced degrees. These results suggest that our sampling approach was successful in identifying knowledgeable key informants.

Follow-up survey. Approximately 30 months following the mailing of our initial survey, we conducted a follow-up survey to test our three longitudinal hypotheses (H_8, H_9, and H_{10}). We sent surveys to 152 of our original respondents (three respondents did not provide contact information). Surveys for 27 firms were undeliverable because of a combination of factors, leaving a final sampling frame of 125 firms. Of the surveys, 73 were returned for an effective response rate of 58%. Of the 73 responding firms, 56 (77%) were located in an optics cluster. The firms that responded to the follow-up survey were statistically similar to the non-responding firms.

Measures and validation

Measure development began with field interviews and pretests of the survey among several people who were connected to the U.S. optics industry. These efforts helped develop and refine our measurement scales and general survey design. Subsequently, we detail the measures we used to assess our key constructs and control variables, and we provide their intercorrelations, reliability indexes, and descriptive statistics in Table 1. The specific wording and scaling used for each measure appear in the Appendix. To ground our measurement assessment, we instructed all respondents to "focus on one specific new product project that either has recently concluded or has been active over the past six months."

Key knowledge provider. We asked respondents to select the most important optics firm or research institution their firm had been in contact with during the focal project and to classify the nature of their relationship with this organization (e.g., supplier, customer, competitor). They were told that formal or contractual relations with this organization were not necessary. We refer to this organization as the key knowledge provider. The majority of key knowledge providers were channel members (suppliers = 40%, customers = 22%). The rest were research institutions (19%), alliance partners (12%), competitors (2%), and others (5%).

Geographic proximity. We assessed geographic proximity by asking respondents to report the locations and distances (in miles) of the optics firm or research institute they identified as a key knowledge provider. We confirmed (and adjusted when necessary) this self-reported distance by calculating the actual geographic distance between the respondent's firm and the key knowledge provider using distance calculation applications (e.g., MapQuest).

As Table 1 shows, on average, the firms in our sample were located more than 1000 miles from their key knowledge provider. Of the firms, 33% were located less than 100 miles from the key knowledge provider (i.e., within a two- hour drive), whereas 20% were located more than 2000 miles from the key knowledge provider. To control for this distributional skewness, we transformed geographic distance using a log transformation.

Relational tie strength. We measured strength of the relational tie between the respondent's firm and the focal knowledge provider with a five-item version of the relational embeddedness scale that Rindfleisch and Moorman (2001) developed. As Granovetter (1985) notes, highly embedded relations are composed of firms that share strong ties with one another. We assessed relationship embeddedness in both our initial and follow-up surveys (r = .74). This scale displayed strong reliability ($\alpha_{initial}$ = .91, $\alpha_{follow\text{-}up}$ =.91).

Interpersonal communication mode (face-to-face and e- mail). In line with previous research (e.g., Cannon and Homburg 2001; Hansen 1999; Mohr, Fisher, and Nevin 1996), we asked key informants how many times during the average workweek (over the previous six months) they personally communicated with scientists, engineers, or technical workers from the focal knowledge provider using each communication mode (i.e., face-to-face and e-mail). We chose to phrase this measure at an interpersonal level because cluster theory focuses on the role of interpersonal, face-to-face contact in knowledge transfer activity (Porter 1998a, b). The majority of our respondents (70%) were from small firms (i.e., 100 employees or less) and were often the founder, primary scientist, and principal communicator with external knowledge providers. Thus, we believe that our measures of communication mode tap the communication patterns of the person most centrally connected to the focal new product development project.

Knowledge form. The embodied and noncodified nature of tacit knowledge makes knowledge form an inherently difficult construct to measure. Nevertheless, prior research has successfully developed several measures of various aspects of this construct (e.g., Hansen 1999; Sternberg et al. 2000; Zander and Kogut 1995). We used a slightly adapted version of Hansen's (1999) three-item degree-of- knowledge-codification scale, which taps the form of acquired technical knowledge by asking respondents to rate the degree to which the knowledge received by their firm was tacit (cf. codified, written, and

Table 1

Key Measure Statistics

Measure	Mean	Standard Deviation	1	2	3	4	5	6	7	8	9	10	11	12
1. Geographic distance	1119	1420	N.A.											
2. Face-to-face communication	1.30	.89	−.02	N.A.										
3. E-mail communication	2.00	1.17	.05	.09	N.A.									
4. Tacit knowledge form	4.34	1.45	−.14*	.14*	−.08	.69								
5. Process knowledge	2.95	1.45	−.06	.03	.31***	−.14*	.85							
6. Product knowledge	3.21	1.26	.05	−.06	.41***	−.19**	.43***	.88						
7. New product creativity	5.35	1.13	−.03	−.17**	.11	−.04	.26***	.33***	.89					
8. New product development speed	4.10	1.09	.02	−.07	.02	−.27***	.21***	.06	.24***	.85				
9. Relational tie strength	4.97	1.07	−.10	.05	.24***	−.19**	.35***	.37***	.15*	.15*	.91			
10. Annual sales (in millions of dollars)	94.6	617	−.05	−.03	−.05	−.03	−.10	.01	.11	.08	−.01	N.A.		
11. Number of employees	327	1593	−.06	−.05	−.06	−.05	−.09	.01	.10	.10	.00	.94***	N.A.	
12. Personal interaction	6.30	6.87	−.16**	−.03	.04	−.16**	−.07	−.07	.12	−.02	.16**	.00	−.01	N.A.
13. Organizational interaction	6.42	6.03	−.12	.06	−.02	.02	.03	.03	.08	−.11	.18**	.08	.07	.58***

* $p < .10$.
** $p < .05$.
*** $p < .01$.

Notes: The coefficient alpha for each measure is on the diagonal, and the intercorrelations among the measures are on the off-diagonal. N.A. = not applicable. The correlations reported for geographic distance are based on actual distances. Our analyses are based on log-transformed distance.

documented). Thus, higher scores indicate higher degrees of tacitness, and lower scores indicate higher degrees of codification. The alpha for this measure was .69.

Knowledge acquisition (product and process). To assess the amount of knowledge acquired from the firm's key knowledge provider, we adapted scales that Rindfleisch and Moorman (2001) developed to measure process knowledge acquisition (e.g., new manufacturing processes) and product knowledge (e.g., key product specifications). Note that knowledge content acquisition is assessed independently from the form (tacit or codified) of acquired knowledge because either process or product knowledge can be codi- fied or noncodified (Kogut and Zander 1992). Both mea- sures displayed good reliability ($\alpha_{process}$ = .85, $\alpha_{product}$ =.88).

New product outcomes (creativity and speed). To assess new product creativity and development speed, we used slightly adapted versions of scales that Rindfleisch and Moorman (2001) developed, and we assessed both out- comes in our initial and follow-up surveys. These measures displayed strong reliability in both surveys (initial survey: $\alpha_{creativity}$ = .89, α_{speed} = .85; follow-up survey: $\alpha_{creativity}$ = .88, α_{speed} = .88) and were significantly correlated over time ($r_{creativity}$ = .41, $p < .001$; r_{speed} = .31, $p < .001$).

Control variables. We also asked respondents to report the number of years they (length of personal interaction) and their organization (length of organizational interaction) had interacted with the knowledge provider and the size of their firm in terms of annual sales revenue and number of employees.

Examination of dimensionality and discriminant validity. We assessed the unidimensionality of the measures we used in our initial survey with a confirmatory factor analysis model using LISREL 8.3. As Table 2 shows, all factor loadings were significant, and all fit indexes met or exceeded recommended levels (comparative fit index [CFI] = .90, nonnormed fit index [NNFI] = .90, root mean square error of approximation [RMSEA] = .07, and standardized root mean square residual [SRMR] = .08). Next, we calculated the composite reliability using the procedures that Fornell and Larcker (1981) suggest. We also examined the parameter estimates and their associated t-values and calculated the average variance extracted (AVE) for each construct (Gerbing and Anderson 1988). As Table 2 shows, composite reliabilities ranged from .78 to .90, indicating acceptable levels of reliability for the constructs (Fornell and Larcker 1981). Finally, the AVEs ranged from 51% to 61%, which are greater than the recommended level of 50% (Bagozzi and Yi 1988). We assessed discriminant validity by calculating the shared variance between all possible pairs of constructs and verified that they were less than the AVE for all individual constructs, thus satisfying Fornell and Larcker's (1981) test and indicating that our multi-item scales display adequate discriminant validity.

ANALYSIS AND RESULTS

We analyzed the data from our initial survey using structural equations modeling (LISREL 8.3). Specifically, we specified a model that examined our a priori hypothesized relationships (Model 1), a model that examined a post hoc set of expanded relationships (Model 2), and a model that investigated a competing perspective (Model 3). The standardized parameter estimates and standard errors for Model 1 and Model 2 appear in Table 3. We analyzed the data from our follow-up survey using regression analysis because the size of our follow-up sample (n = 73) did not allow us to employ structural equations modeling techniques (see Table 4).

Measurement model

In line with Bagozzi and Heatherton's (1994) suggestions, we created two composite items for each latent factor to serve as its indicators. We followed this approach for our five latent constructs (i.e., noncodified knowledge, process and product knowledge, and creativity and speed of new product development). We also included our three single- item measure constructs (i.e., geographic proximity and face-to-face and e-mail communication) and

Table 2
Measurement model parameters

Items	Creativity	Speed	Product Knowledge	Process Knowledge	Tacit Knowledge
Create1	.66 (8.91)				
Create2	.81 (11.94)				
Create3	.86 (12.98)				
Create4	.81 (11.80)				
Create5	.73 (10.28)				
Create6	.78 (11.11)				
Speed1		.76 (10.62)			
Speed2		.74 (10.07)			
Speed3		.88 (12.94)			
Speed4		.72 (9.86)			
Product1			.75 (9.74)		
Product2			.68 (8.69)		
Product3			.63 (7.78)		
Product4			.71 (9.10)		
Process1				.78 (11.02)	
Process2				.67 (9.02)	
Process3				.83 (12.16)	
Process4				.82 (11.93)	
Process5				.80 (11.61)	
Tacit1					.78 (9.83)
Tacit2					.89 (11.22)
Tacit3					.51 (6.28)
Composite reliability	.90	.86	.79	.89	.78
Variance extracted (%)	60	60	51	61	55
Highest shared variance (%)	12	12	20	20	11

Notes: The numbers indicate standardized factor loading. The t-values are in parentheses.

fixed their error variance on the basis of the reliabilities of each measure (Hayduk 1987). Finally, we included four control variaables (annual sales, number of employees, length of personal interaction, and length of organizational interaction), which we treated as independent variables along with geo- graphic proximity.

Model 1 (hypothesized model) and model 2 (expanded model)

For efficiency purposes, we focus on the results from Model 1 and discuss only the paths in Model 2 that are substantively different from Model 1. With the exception of H_2, we describe our results in the order they are listed in our conceptualization and as portrayed from left to right in Figure 1. We save our discussion of the findings for H_2 until the competing model section (Model 3) because it entails the specification and testing of an alternative model. The fit statistics associated with Model 1 are reasonable (CFI = .88, IFI = .87, RMSEA = .08, and SRMR = .09), the overall R^2 is .34, and the explained variance of dependent variables ranged from .11 (creativity) to .56 (e-mail). However, model fit could still be improved. Therefore, we estimated a second model (Model 2) that duplicated the paths shown in Figure 1, adding relational tie strength as a moderator of the paths between geographic proximity and communication mode and the paths between knowledge acquisition and new product outcomes. The fit for this expanded model (CFI = .90, IFI = .91, RMSEA = .06, and SRMR = .09) is superior to Model 1.

Our conceptual model suggests that the effect of communication mode (face-to-face and e-mail) on knowledge content (process and product) is moderated by the strength of the relationship between the focal organization and its knowledge provider. We tested these moderating effects through multigroup analyses (Stone and Hollenbeck 1989) by partitioning our sample on the basis of a median split of relational tie strength (median = 5.0). We then assessed the invariance of the parameter estimates between the strong and the weak relational tie subgroups by comparing the chi- square from a model that constrained the paths between communication mode and knowledge content to equality with that of a

Table 3
Comparison of Results from Model 1 and Model 2

	Paths	Model 1: All Firms		Model 2: Weak Ties	Model 2: Strong Ties
H_{1a}	Geographic distance → face-to-face communication	−.19** (−2.07)		.20 (n.s.)	−.32*** (−2.82)
H_{1b}	Geographic distance → e-mail communication	.07 (n.s.)		−.15 (n.s.)	.29** (2.15)
H_2	Face-to-face communication → noncodified knowledge	.21** (2.31)		−.10 (n.s.)	.32*** (3.70)
H_3	E-mail communication → noncodified knowledge	−.15* (1.77)		.14 (n.s.)	−.19** (−2.53)
		Weak Ties	Strong Ties		
H_{4a}	E-mail communication → product knowledge	.31*** (2.71)	.60*** (5.80)	.33*** (3.23)	.53*** (5.30)
	E-mail communication → process knowledge	.09 (n.s.)	.34*** (4.45)	.07 (n.s.)	.35*** (4.05)
H_{4b}	Face-to-face communication → process knowledge	.01 (n.s.)	.03 (n.s.)	.00 (n.s.)	.07 (n.s)
	Face-to-face communication → product knowledge	−.15* (−1.72)	−.39*** (−3.05)	−.26** (−2.92)	−.32** (−2.78)
H_5	Product knowledge → creativity	.33*** (3.70)		.04 (n.s.)	.46** (3.91)
H_6	Process knowledge → creativity	.16** (1.99)		.12 (n.s.)	.21** (2.09)
H_7	Product knowledge → speed	−.03 (n.s.)		−.01 (n.s.)	−.01 (n.s.)
H_8	Process knowledge → speed	.20** (2.16)		.21* (2.37)	.21** (2.37)
H_{9a}	Noncodified knowledge → creativity	.05 (n.s.)		.02 (n.s.)	.02 (n.s.)
H_{9b}	Noncodified knowledge → speed	−.12 (n.s.)		−.17* (−1.74)	−.17* (−1.74)

*$p < .10$.
**$p < .05$.
***$p < .01$.
Notes: We report the common metric completely standardized solution. The t-values are in parentheses. n.s. = not significant.

model that allowed these paths to vary freely. This analysis shows that the chi-square difference between the constrained and unconstrained models is statistically significant ($\chi^2(9) = 17.02$, $p < .05$), suggesting the presence of a moderating effect of relational ties.

Our results indicate that geographic distance (i.e., the inverse of proximity) is negatively related to face-to-face communication (b = –.19, p < .05). In effect, as the distance (proximity) between optics organizations increases, their frequency of face-to-face communication decreases (increases). Thus, H_{1a} is supported. We also find that geographic distance does not affect the frequency of e-mail communication between optics organizations (b = .07, not significant [n.s.]), in support of H_{1b}. This suggests that more proximal organizations have a greater tendency to exchange knowledge through face-to-face (but not electronic) communication.

The results from Model 2, however, reveal that the relationship between geographic proximity and face-to-face communication found in Model 1 is limited to firms that have strong ties to their key knowledge providers (strong ties: b = –.32, p < .01; weak ties: b = .20, n.s.). In other words, being in close proximity to key knowledge providers appears to enhance face-to-face contact only among relationally close firms. Model 2 also shows that though geographic proximity may be unrelated to e-mail communication at an overall level, the presence of strong ties appears to encourage physically distant firms to maintain contact through electronic means (strong ties: b = .29, p < .05; weak ties: b = –.15, n.s.).

Next, we examined the effects of communication mode on the form of knowledge acquired. As cluster theorists predict, we find that face-to-face communication is positively related to noncodified (tacit) knowledge acquisition (b =.21, p < .05). We further find that e-mail communication is negatively related to noncodified knowledge acquisition (b = –.15, p < .10). Because our hypothesis (H3) investigates the relative effects of communication mode on non- codified knowledge acquisition, we conducted a chi-square difference test. The difference between the two models is significant ($\chi^2(1) = 6.21$, p < .001), suggesting that the effect of face-to-face communication is significantly larger than the effect of e-mail communication on noncodified knowledge acquisition. These results provide support for H3. The results from Model 2 further show that the effects of face-to-face and e-mail communication are magnified in the presence of strong ties (b = .32, p < .01; b = –.19, p <.05).

Table 4
Longitudinal Results

Hypotheses	Variables	New Product Creativity at Time 1	New Product Creativity at Time 2	New Product Speed at Time 1	New Product Speed at Time 2
H_8	Product knowledge	.30** (2.08)	.42*** (2.84)	.05 (.75)	.02 (.14)
H_9	Process knowledge	.24* (1.67)	–.17 (–1.18)	.22 (1.55)	.14 (.92)
$H_{10a,\ b}$	Noncodified knowledge	.01 (.09)	–.14 (–.99)	–.33** (–2.37)	–.27* (–1.89)
	Length of personal interaction	–.01 (–.07)	–.08 (–.48)	–.08 (–.52)	.09 (.52)
	Length of organizational interaction	.06 (.37)	.22 (1.30)	–.14 (–.86)	.24 (1.4)
	Annual sales	–.44* (1.85)	.22 (.90)	–.39* (1.65)	–.23 (–.93)
	Number of employees	.28 (1.15)	–.33 (–1.32)	.35 (1.43)	.08 (.32)
	R^2	.27	.23	.26	.21
	Adjusted R^2	.16	.12	.15	.09
	F value (degrees of freedom: numerator, degrees of freedom: denominator)	2.52** (7, 48)	2.05* (7, 48)	2.43** (7, 48)	1.80* (7, 47)

*p < .10.
**p < .05.
***p < .01.
Notes: We collected the follow-up (Time 2) survey data 30 months after the initial (Time 1) survey data. We ran both the Time 1 and Time 2 regressions using the sample size of 73 respondents that responded to the Time 2 survey. The results using the entire sample (n = 155) are similar.

In H_{4a}, we propose that e-mail communication is associated with a greater amount of product knowledge acquisition for firms with strong ties to their knowledge provider. Model 1 indicates that e-mail communication is positively related to product knowledge acquisition for both strong and weak ties ($b = .60$, $p < .01$; $b = .31$, $p < .01$). A chi- square test comparing a constrained with an unconstrained model shows a significant difference ($\chi^2(1) = 7.45$, $p < .01$), in support of H_{4a}. In addition, we find that e-mail communication is related to the process knowledge acquisition for strong ties ($b = .34$, $p < .01$) but not for weak ties ($b = .09$, n.s.). These results show that electronic modes of communication, such as e-mail, are positively associated process and product knowledge acquisition when firms have strong relationships with their knowledge providers.

In H_{4b}, we propose that face-to-face communication is associated with a greater amount of process knowledge acquisition for firms with strong ties to their knowledge provider. This hypothesis is not supported; face-to-face communication has no effect on process knowledge for either weak or strong ties ($b = .01$, n.s.; $b = .03$, n.s.). More- over, we find that face-to-face communication has a nega- tive effect on the product knowledge acquisition for both strong and weak ties ($b = –.39$, $p < .01$; $b = –.15$, $p < .10$).

Next, we examined the impact of knowledge content and form on new product outcomes. As we predicted, prod- uct knowledge acquisition is more strongly associated with greater new product creativity ($b = .33$, $p < .01$) than is process knowledge acquisition ($b = .16$, $p < .05$). A chi- square test in which we allowed the effect of product knowledge on new product creativity to vary compared with one in which we constrained it reveals a significant differ- ence ($\chi^2(1) = 6.31$, $p < .01$), in support of H_5. We also find that process knowledge acquisition is more strongly associ- ated with accelerated speed of new product development ($b = .20$, $p < .05$) than is product knowledge acquisition ($b =–.03$, n.s.), in support of H_6. However, the results do not support H_7, which predicts that noncodified (tacit) knowl- edge enhances creativity ($b = .05$, n.s.) and slows down development speed ($b = –.12$, n.s.). This suggests that the type of content acquired from knowledge providers is more strongly associated with new product outcomes than is the form of knowledge acquired.

Finally, Model 2 shows that the positive linkages between both product knowledge (strong ties: $b = .46$, $p <.01$; weak ties: $b = .04$, n.s.) and process knowledge (strong ties: $b = .21$, $p < .01$; weak ties: $b = .12$, n.s.) and new prod- uct creativity are limited to firms with strong ties to their knowledge providers. Thus, it appears that firms that acquire knowledge from weakly tied providers are unable or unwilling to use this knowledge to develop more creative new products.

Model 3 (competing model)

Our specification of relational ties as (1) unrelated to geo- graphic proximity and (2) a moderator of the effect of communication frequency on knowledge acquisition represents a dramatic departure from the way that cluster theory depicts this construct. Specifically, cluster theorists argue that relational ties are a direct outcome of geographic proximity and have a direct influence on knowledge acquisition (Porter 1998b; Rosenfeld 1997).

To test this alternative theoretical perspective explicitly, we specified a competing model that was identical to Model 1 except that (1) we specified a path between geographic proximity and relational tie strength and (2) we removed the moderating paths of relational tie strength between communication mode and knowledge type. In effect, this competing model specifies relational tie strength as a mediator rather than a moderator of the effect of geographic proximity on higher-level cluster outcomes. The results indicate that this alternative model is largely inferior to our hypothesized model; its fit statistics (CFI = .87, NNFI = .86, RMSEA = .12, and SRMR = .15) are weaker than those of Model 1. Moreover, this model revealed that the path between geographic distance and relationship tie strength is not significant ($b = –.04$, n.s.). These results not only pro- vide strong support for H_2 but also offer significant validity to our moderating model of relational tie strength.

Test of longitudinal hypotheses

We examined the longitudinal effect of knowledge form and content on new product development outcomes by specify- ing two regression models. In both models, the measures of noncodified knowledge, process knowledge, and product knowledge from our initial survey were the independent variables. The dependent variables were our follow-up mea- sures of new product creativity and development speed that we collected 30 months later. As a baseline comparison, we also specified two models that used the same independent variables, but we used the measures of creativity and speed from our initial survey as the dependent variables. As Table 4 shows, the effect of product knowledge on new product creativity is stronger at Time 2 ($b = .42$, $p < .01$) than Time 1 ($b = .30$, $p < .05$), and this difference is significant ($p <.05$). In contrast, process knowledge is unrelated to new product development speed at both Time 1 ($b = .22$, n.s) and Time 2 ($b = .14$, n.s.). Finally, noncodified knowledge is unrelated to creativity at both Time 1 ($b = .01$, n.s.) and Time 2 ($b = –.14$, n.s.) and is negatively related to new product development speed at both Time 1 ($b = –.33$, $p <.05$) and Time 2 ($b = –.27$, $p < .10$). This difference is not significant. Collectively, these results support H_8 but not H_9 or H_{10}.

DISCUSSION

Our research paints a portrait of the role of geographic distance in new product development that is markedly different from that offered by the traditional views of industry clusters and marketing strategy. Specifically, our results show that (1) geographic proximity is related to face-to-face communication but is unrelated to relational ties, (2) relational ties moderate several linkages in the path between geo- graphic proximity and new product development, (3) face- to-face communication is less effective than electronic communication as a means of knowledge acquisition, and (4) knowledge content has a greater effect on new product development than knowledge form. In combination, this set of results is rather surprising when it is juxtaposed with extant theory on industry clusters and marketing strategy, and it offers several insights into the relationship between geographic proximity and new product development.

Theoretical implications

At first glance, our results appear to suggest that distance still matters. The results of both Model 1 and Model 2 show that firms located in closer physical proximity engage in more frequent face-to-face contact. However, our analysis also reveals that geographic proximity is unrelated to the presence of strong relational ties between knowledge providers and recipients. According to cluster scholars such as Saxenian (1994, p. 104), “there is little doubt that geo- graphic proximity fosters the frequent interaction and personal trust needed to maintain these relationships.” How- ever, our results question the generalizability of such assertions.

It appears that even for firms located in close physical proximity, relational ties must be nurtured and cannot be taken for granted. As organizational scholars observe, firms need to consider both geographic closeness and relational closeness in understanding interfirm behavior (Ghemawat 2001). Our results support and enrich this observation by showing that relational ties are a key moderator for nearly every path in the chain that links geographic proximity to new product development. In summary, nearly all the effects of geographic proximity depend on strong relational ties.

Another widely held assumption among both cluster theorists and knowledge scholars is the necessity of face-to- face contact for the transfer of noncodified (tacit) knowledge. Although our results do not wholly refute such claims, they add some necessary refinement by showing that though face-to-face communication may facilitate the transfer of tacit forms of knowledge, its value in transfer- ring the content of knowledge may be matched or exceeded by other forms of communication, such as e-mail. As Table 3 shows, both process and product knowledge content are critical to new product development because product knowledge enhances new product creativity and process knowledge enhances new product development speed. Our longitudinal data show that knowledge in noncodified form has no effect on new product creativity and hampers new product development speed. Thus, our findings suggest that e-mail and other means of electronic communication are more critical to new product development than is frequent face-to-face contact with external knowledge providers.

Recent research on virtual teams indicates that people can work effectively together without ever meeting in per- son (Cummings 2004; Majchrzak et al. 2004). Thus, e-mail and other forms of electronic communication may be attractive from an efficiency standpoint, regardless of geographic distance, because knowledge seekers may be willing to trade off the richness of face-to-face contact for the timeliness and low cost of an e-mail message. The knowledge benefits of e-mail provide further support for those heralding the "death of distance" and advocates of virtual technologies in general.

Two of our most surprising findings are that face-to-face communication is unrelated to process knowledge acquisition, even when there are strong relational ties with the knowledge provider (contrary to H4b), and that it is negatively related to product knowledge acquisition (see Table 3). How can this be? In an attempt to answer this question, we conducted follow-up interviews with a few of our respondents. These interviews revealed three possible explanations. First, it appears that face-to-face communication with knowledge providers occurs mainly at the start and end of a project. Thus, the bulk of communication during the active R&D and knowledge acquisition phase of a project takes place at a distance. Second, respondents noted the generally unproductive nature of face-to-face meetings in a new product development context, which can apparently even be counterproductive. Third, they suggested that a high level of face-to-face contact could be a sign of a troubled relationship (i.e., one in which little exchange of product knowledge takes place). These possibilities lend further support to the primacy of e-mail as a means to acquire relevant new product-related knowledge.

Managerial implications

High-tech firms that want to enhance their new product development outcomes can draw several insights from our research. First, in contrast with the recommendations of cluster advocates about the importance of geographic proximity, our results suggest that there is no magic that stems automatically from being located near other firms or research institutions in the same industry. Instead, a firm must first develop strong relationships with key knowledge providers to gain access to knowledge, regardless of whether these organizations are near or far. In the absence of close relationships, simply being located in close physical proximity to a knowledge provider does not lead to enhanced communication, improved knowledge acquisition, or better new product outcomes. Geographic proximity may offer an opportunity for relationship development, but this opportunity must be acted on to provide benefits. Therefore, a key managerial priority should be to develop and nurture relationships with potential knowledge providers regardless of their physical location.

Second, after firms establish close relations (at any distance), e-mail can be an effective and efficient means for acquiring both product and process knowledge. As we previously noted, some of our respondents revealed that the socially laden nature of face-to-face meetings can actually be counterproductive. In contrast, e-mail appears to help focus communication on the business at hand, thus resulting in more effective transfer of knowledge that is useful for new product development. The relatively impersonal nature of e-mail may provide added efficiency and clarity by avoiding the symbolic and social barriers that often accompany face-to-face interactions (Durrance 1998; Trevino, Lengel, and Daft 1987). This efficiency advantage of electronic communication should further increase as instant messaging and other interactive technologies become more widely used.

Limitations and future research directions

Our conceptualization and measurement

assume that face- to-face communication enables a rich and interactive exchange of information in real time, whereas e-mail communication is leaner, less interactive, and off-line in nature. This represents an important limitation of our current study; richness is not only inherent in a communication medium but also dependent on contextual factors such as the nature of interactions between the sender and the receiver and the meanings ascribed to them (Lee 1994). Further research could add value by exploring the nuances of these modes of communication in the context of new product development.

In this study, we focused on one important aspect of tacit knowledge: the degree of tacitness (i.e., noncodification) of information acquired from the knowledge provider; however, this study did not directly assess other aspects, such as the absolute quantity of information acquired in tacit form. Because e-mail communication in our sample was more frequent than face-to-face meetings, the (unmeasured) amount of tacit information acquired may have been small compared with the amount of codified information received. Different respondent interpretations of this measure may have led to the underreporting of the tacitness of information acquired and perhaps may have contributed to the nonsignificant effects of tacit knowledge on new prod- uct creativity and development speed, contrary to our pre- dictions in H_7 and H_{10}.

Another limitation of our work is its focus on optics-related firms. Although our sample covers applications in diverse product subcategories, a study that covers a broader spectrum of industries would enable researchers to test the generalizability of our findings. Perhaps geographic proximity plays a more important role in the establishment of relational ties and the development of new products in lower-technology industries, such as furniture or textile manufacturing.

Further research could also add value by expanding and enriching our measures of new product outcomes. Our use of survey self-reports of new product creativity and speed provides snapshots of these processes at individual times. It would be valuable to supplement these snapshots with either ethnographic accounts of the role of geographic prox- imity in new product development as these processes unfold in real time or more precise accounts of proximity's impact on actual (rather than perceived) new product outcomes. Our examination of the benefits of geographic proximity is also limited by our focus on knowledge acquisition. Further research should examine other potential benefits of being located near other organizations in the same industry, such as access to a ready supply of qualified workers and the prestige of being a member of a well-known cluster.

APENDIX MEASURES

Mode of communication (frequency)

We adapted the measure for mode of communication from the work of Hansen (1999) and Mohr, Fisher, and Nevin (1996). We measured it on a five-point scale ranging from 1 ("less than once a week") to 5 ("more than once a day").

1. Face-to-face: Over the past six months, how many times during the average workweek did you personally communi- cate directly with scientists, engineers, or technical workers from this organization in person?
2. E-mail: Over the past six months, how many times during the average workweek did you personally communicate directly with scientists, engineers, or technical workers from this organization by e-mail?

Tacit knowledge form

We adapted the measure for tacit knowledge from the work of Hansen (1999). We measured it on a seven-point scale.

1. Considering all the types of technical information that you received from this organization (as indicated on the previous page), how well documented was this information? (reversed) (1 = "it was not well documented," 4 = "it

was somewhat well documented," and 7 = "it was very well documented")

2. How much of this technical information was thoroughly explained to your firm in writing (i.e., written reports, manuals, faxes, e-mails, etc.)? (reversed) (1 = "none of it was," 4 = "half of it was," and 7 = "all of it was")
3. Overall, how would you describe the type of technical information that you acquired from this organization? (1 = "mainly formal reports, manuals, documents, and so forth," 4 = "half know-how and half reports and documents," and 7 = "mainly informal practical know-how, tricks of the trade")

Process knowledge

We adapted the measure for process knowledge from the work of Rindfleisch and Moorman (2001). We measured it on a seven-point scale ranging from 1 ("low amount") to 7 ("high amount").

Please rate the amount of new product-related informa- tion that your firm has acquired from this organization over the past six months in the following areas:

1. Information about new manufacturing processes
2. Insights into new ways to approach product development
3. Information about new ways of combining manufacturing activities
4. Insights about key tasks involved in the production process
5. Insights into new ways to streamline existing manufacturing processes

Product knowledge

We adapted the measure for product knowledge from the work of Rindfleisch and Moorman (2001). We measured it on a seven-point scale ranging from 1 ("low amount") to 7 ("high amount").

Please rate the amount of new product-related informa- tion that your firm has acquired from this organization over the past six months in the following areas:

1. Information about R&D projects conducted outside your firm
2. Research findings related to new product development
3. Information about end-user requirements
4. Information about competitors' technology

New product creativity

We adapted the measure for new product creativity from the work of Rindfleisch and Moorman (2001). We measured it on a seven-point semantic differential scale.

Please circle the degree to which each of the following items provides an accurate description of this new product development project over the past six months:

1. Very ordinary for our industry/very novel for our industry
2. Not offering new ideas to our industry/offering new ideas to our industry
3. Not creative/creative
4. Uninteresting/interesting
5. Not capable of generating ideas for other products/capable of generating ideas for other products
6. Not promoting fresh thinking/promoting fresh thinking

Speed of new product development

We adapted the measure for speed of new product development from the work of Rindfleisch and Moorman (2001). We measured it on a seven-point semantic differential scale.

Please circle the degree to which each of the following items provides an accurate description of this new product development project over the past six months:

1. Far behind our project timeline/far ahead of our project timeline
2. Slower than the industry norm/faster than the industry norm
3. Much slower than we expected/much faster than we expected
4. Slower than our typical product development time/faster than our

typical product development time

Relational tie strength

We adapted the measure for relational tie strength from the work of Rindfleisch and Moorman (2001). We measured it on a seven-point scale ranging from 1 ("strongly disagree") to 7 ("strongly agree").

1. We feel indebted to this organization for what they have done for us.
2. Our interactions with this organization can be defined as "mutually gratifying".
3. Maintaining a long-term relationship with this organization is important to us.
4. Our business relationship with this organization could be described as "cooperative" rather than an "arm's-length" relationship.
5. We expect to be interacting with this organization far into the future.

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Acknowledgement: Reprinted with permission from the Journal of Marketing, published by the American Marketing Association, 2005 69(4): 44 – 60.