The Structure of Knowledge and Seller-Buyer Networks in Markets for Emergent Technologies

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Abstract

This empirical study compares the impact of knowledge structures on relational patterns in markets for emergent technology and in a mass market within the electronics industry. We hypothesized that in markets for emergent technologies, sellers and buyers do not have a common image of product use, and to reach it they must communicate contextual knowledge rooted in engineering practice. Furthermore, insofar as knowledge is contextual (as opposed to articulated in a mass market), sellers' and buyers' experts must engage in an intense technological dialogue. These hypotheses were tested by a key-parametric qualitative field study and quantitative network analysis. Communication activity was found more intense in the seller-buyer network in the emergent technology market than in the mass market. The seller-buyer network of emergent technology was also more hierarchical, with technical experts located at the center of the technological dialogue regarding product application. Shared practice and co-development proved to be dominant forms of work organization in the market for emergent technologies. By contrast, sequential development epitomized the activities in the seller-buyer network of the standard product. Implications for network theory, economic sociology, and organization studies are discussed.

Keywords: knowledge structure, social networks, uncertainty, vertical integration, quasi-firm, emergent technology

Introduction

The number of studies treating the current digitalization of production systems and services as a technological revolution and pointing to a shift to technical work and to a technical workforce has recently multiplied (Barley 1996; McLoughlin and Clark 1994; Pentland 1991). While the influence of the micro-electronics revolution on production processes, services, and the occupational structure itself has been thoroughly investigated (Attwell 1987; Barley 1996; Zuboff 1988), no study has systematically explored its impact on relational patterns in markets for emergent technologies. This study is designed to narrow this gap by comparing the structure and content of seller-buyer networks in an emergent technology market with networks in a market for more standard products.

High-technology markets assume growing importance today as an increasing number of 'heartland technologies' (McLoughlin and Clark 1994: 13), supporting the digitalization of the technological infrastructure, are traded in

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them. Despite their importance, we know little about the inner workings of emergent technology markets. The few studies that have ventured to explore exchange behaviors in high-tech markets point to some similarities to pre-industrial craft markets, rather than advanced industrial mass markets. Like craft markets, innovative products in micro-electronics are produced by engineering boutiques in a craft-like production mode (Freeman 1986; McLoughlin and Clark 1994). The producers, often a small group of design engineers, have an intimate knowledge of their product, which they are reluctant to share with prospective buyers. Thus, as in craft markets, buyers in high-tech markets experience uncertainty regarding products' quality and production costs. But unlike craft markets, recent literature suggests, the uneven structure of knowledge in high-tech markets goes beyond issues of quality and cost of products. In addition, product application in markets for emergent technologies is not fixed, but instead enjoys an 'interpretive flexibility' (Pinch and Bijker 1987). Social actors in seller-buyer networks in high-tech markets, such as sellers, buyers, and mediators of exchange, hold different interpretations of the design and use of the artifact being sold. To complete a sale, sellers and buyers must arrive at a shared image of use and must customize products (Darr 2000, 2002).

Similarly, Von Hippel (1988) finds that 'lead users' (mainly large buyers) are major innovators in high-tech markets, since they often put innovative tools and techniques produced by small firms to a use that diverges from manufacturers' expectations. Manufacturers, or sellers, search for information about new applications for their products to exploit emerging niche markets. But the search for information about product application is often hampered by the 'sticky' quality of the information being sought (Von Hippel 1994). The information that sellers and buyers require to arrive at a shared image of use is contextual and deeply rooted in engineering practice.

In sum, the literature cited above suggests that, unlike the case of mass-produced or craft-produced products, a major source of uncertainty in the sales of emergent technologies is product application. Consequently, the successful completion of sales transactions in high-tech markets depends on the transfer of contextual rather than codified knowledge in the customization process. In this study, we propose that the unique combination of uncertainties in markets for emergent technologies, and the types of knowledge that need to be communicated to overcome it, shape distinct relational patterns among firms. Moreover, we wish to explore how the problem associated with the transfer of contextual and non-standard knowledge affects the structure of microlevel ties and the coordination mechanism between sellers and buyers in high-tech markets.

To analyze seller-buyer networks in high-tech markets an analytical distinction between codified and contextual knowledge is warranted. This distinction is absent from most studies of seller-buyer networks in contemporary markets. Standard or codified knowledge, typical of a mass market, is easily articulated and transferred through the use of schematics and formal models and forms. It can be easily symbolized, automated, and, most important, communicated and interpreted beyond locale. For example, in the mass market for cars, professional magazines that rate cars according to price and quality represent a body of codified knowledge, which allows a more symmetric distribution among buyers and sellers. By contrast, contextual knowledge, which needs to be communicated in the customization process, is embedded locally; it is non-standard, and thus cannot be easily articulated or understood outside a specific social context. Contextual knowledge cannot be easily deconstructed to a machine-like code, nor can it be readily transferred into another site. Hence, it cannot simply be automated or learned through formal means. It has to be transferred via social ties and shared practice (Collins 1993).

While information, a term widely used by economists, is described as easily articulated and transferred, objectively standing as a 'social fact' over and above the person who produces or uses it, the production and use of contextual knowledge is social (Fruin 1997). Other than symbol-type knowledge, other knowledge types (for example, embodied and encultured) can be transferred only by social interaction (Collins 1995). Contextual knowledge is often conveyed through informal ties, sometimes even unintentionally or capriciously (Collins 1974).

In the context of work organization, the transfer of contextual knowledge also depends on extensive on-the-job training and experience-based learning. For example, Barley (1996: 425) notes that semiotic knowledge, which he defines as 'the ability to make sense of subtle differences in the appearance of materials and the behavior of machines', is a critical element of contextual knowledge. He describes how colors, shapes and smells are important elements of the work of science technicians. Social interactions at the lab between the experienced and inexperienced lab technicians are the only source of communicating semiotic knowledge. Through social interactions the novice technicians learn how to 'recognize and interpret minute differences in sensation' that are crucial on the laboratory shop floor. These contextual elements of knowledge contain 'semiotic' understanding of subtleties of operation and applications, comprehension of their local idiosyncrasies, as well as adherence to a specific work style and access to a pool of distributed knowledge and shared local practices (Barley 1996).

Sociologists of scientific knowledge have recognized the crucial role of contextual knowledge in scientific practice. They have found that the translation of a scientific problem from one setting into a different context involves tacit knowledge, subtle interpretation, and selective rendition of the problem. Dynamic social linkages among scientists are crucial for the transfer of this type of knowledge and produce the shared base for scientific interpretations. In different contexts and within different 'invisible colleges' (Crane 1972), translations of the same scientific 'fact' may take distinct forms (Knorr-Cetina 1981, 1999; Latour and Woolgar 1979). The literature above suggests that contextual knowledge is a crucial element in the sale of emergent technology. Thus, we hypothesize that:

H1: Contextual knowledge, rather than codified as in a mass market, will be communicated over the seller-buyer network of emergent technology. We *expect to find only the transfer of codified knowledge in the seller-buyer network of standard products.*

Social Networks and the Management of Market Uncertainty

Network analysts have often illustrated that market uncertainty is mitigated or managed through social ties. For example, the adaptation of a new product to market needs and the way it is received by clients are usually affected by cohesive networks and communication flows through strong ties. In addition, strong ties seem to assist in overcoming the uncertainty associated with the introduction of new products (Burt 1987; Coleman et al. 1957; Rogers and Kincaid 1981). Other kinds of uncertainty are also resolved via the construction and maintenance of either strong or weak ties. For example, female middle managers, who succeed in breaking the corporate 'glass ceiling', are typically promoted through strong ties, while male managers' promotion is a positive function of their weak ties (Burt 1992: Ch. 4). While rice in South-East Asia is traded on a spot market, composed mainly of 'arm's-length' ties, raw rubber, whose quality is difficult to assess, is exchanged via repeated ties, where previous successful transactions reinforce trust and reduce uncertainty (Oberschall and Leifer 1986). Similarly, while tin is traded on a spot market, aluminum, whose trade is highly uncertain, is exchanged within dense, vertically integrated ties (Hennart 1988). The repeated ties among exchange partners in markets with high levels of uncertainty can be described as a 'quasi-firm', a cross-organizational arrangement where transactions recur, resembling vertical integration, but without legal and bureaucratic structures. Consequently, quasi-integration forms enjoy both economies of scale and the flexibility necessary to deal with market uncertainty (Eccles 1985; Powell 1990).

Uzzi (1997) claims that sellers and buyers perceive the construction of embedded, rather than arm's-length ties as an efficient exchange behavior, designed to transfer practice-based knowledge. More generally, the literature presents embedded market ties or quasi-firm arrangements as forms of economic exchange structured to facilitate the transfer of contextual or expert knowledge (Ebers 1999; Podolny 1994). Based on the literature above, we hypothesize that:

H2: In the seller-buyer network of emergent technology, contextual knowledge will be communicated bi-directionally, coupled with quasi-firm arrangements, such as co-development. We expect to find no signs of quasi-firm arrangements in the seller-buyer network of a more standard product.

Uncertainty and Exchange Behaviors in Emergent Technology Markets

Economists and economic anthropologists assert uncertainty to be asymmetric distributions of information regarding the quality and cost of the products being exchanged. They distinguish two market archetypes (craft and mass) by the level of uncertainty they exhibit. In mass markets, low levels of uncertainty regarding quality and cost exist because social institutions, such as brand names and industry standards, allow buyers to counter the uncertainty about quality and cost (Akerlof 1970). Consequently, only buyers in a mass market engage in an extensive information search about products' quality and cost. They seek additional offers to ones already received from sellers (Geertz 1978: 31). In mass markets, sellers and buyers also have a common image of how the product could be used.

By contrast, craft markets are characterized by high levels of uncertainty regarding products' quality and cost. Sellers in a craft market, often the producers, possess intimate knowledge of a product's quality and production costs. But this knowledge is not shared with buyers, who must engage in an intensive information search about products as they explore in depth each offer received from sellers (Geertz 1978: 31), rather than simply seek additional offers. An intensive information search is burdensome for buyers as well as for sellers, who must spend time replying to customers' detailed questions. But similar to mass markets, sellers and buyers in a craft market agree on products' applications.

Lately, anecdotal evidence has emerged that the current digitalization of production systems and services is creating markets for emergent technologies in which actors engage in distinct exchange behaviors. Here, the feasibility of the customization process becomes a source of uncertainty for buyers and sellers (Darr 2002). Sellers' engineers must overcome this obstacle by engaging in an intensive information search. They try to identify and construct informal ties with specific experts on the client's side who have intimate knowledge of the desired application. Given the lack of institutionalization, we can assume that buyers in emergent technology markets are likely to experience uncertainty regarding the quality and cost of products. In light of this unique structure of knowledge, we hypothesize that:

H3: In emerging technology markets, both sellers and buyers will engage in an intensive information search. While buyers will search for information about the product's quality, sellers will search for knowledge of buyers' applications. By contrast, we expect only buyers in the seller-buyer network of a standard product to engage in an extensive information search.

Contextual Knowledge and Experts' Centrality

Knowledge in markets for emergent technologies is ambiguous and unevenly distributed. As part of their attempts to bridge the knowledge gap about product use, actors in seller-buyer networks in a market for emergent technologies communicate and interpret contextual knowledge. The need to communicate local knowledge places the expert engineer at the center of the transaction. In emerging technology markets, which include applications that cannot be understood except contextually, interpretative flexibility can be negotiated and resolved only by those experts who are equipped to decode — most often even intuitively — the subtleties and possible direction of a complex application (Prietula and Simon 1989). Hence, adapter-user interactive learning is vital for the successful development of innovative products, as this knowledge is 'encultured' in occupational communities of experts (Collins 1995; Talmud 1999).

The unique process in high-tech markets of a dynamic co-bridging of the knowledge gap directly links end users and suppliers, without the brokerage of distributors or independent sales representatives (Smith and Laage-Hellman 1992). Inter-firm cooperation between experts links knowledge-transfer activity and the transformation of products through customization (Håkansson and Johanson 1992). Cross-firm relations in which experts play a central role improve control over the development process, the integrity of expert judgment, and the versatility of possible applications (Araujo and Easton 1999: 83–87). Accordingly, inter-firm ties serve as a building block for a latent vertical integration process. The construction of cross-firm temporary network configurations assists the firm to adapt to heterogeneous and flexible requirements (Easton and Araujo 1999). The seller-buyer networks of emergent technology are more heterogeneous in occupational terms, since different areas of expertise must be involved in the sale (Darr 2002). Privileged access to professional networks and occupational communities is required when research and development is contingent upon contextual knowledge (Lipparini and Sobrero 1999; Lütz 1998). Within each transaction certain areas of expertise are more central than others, resulting in a hierarchical network structure.

In contrast to mass markets, in high-tech markets the transfer of blueprints and schematics among experts, representing a body of codified knowledge regarding the application, never suffices to customize products (Darr 2002). Through face-to-face interactions the sales engineers extract contextual knowledge from the client's design engineers. The sellers' experts in emergent technology markets are positioned as front-line workers and must decode the designers' expert rationality (Prietula and Simon 1989) that guides them in designing the application. Since interpretation revolves around a variety of experts engaging in synergetic exchange, we hypothesize that:

H4: To the extent to which products are based on emergent technology, so network size, heterogeneity in occupational terms, and communication intensity increase.

We further present two related hypotheses:

H5a: To the degree to which the required knowledge for the sale is more contextual, experts will be located at the center of the network.

H5b: To the degree to which the required knowledge for the sale is more contextual, seller-buyer networks will be more hierarchical.

Research Site

The data were collected at Filtronics, a small micro-electronics company producing both standard and customized electronic filters and operating in the northeast of the USA. Filtronics's filters were designed to prepare analog signals for digitalization. The filters 'cleaned' the analog signals of any 'noise', thus ensuring high-quality digitalization. They were used in a variety of applications, for example, as part of digital test equipment, in industrial robots, and as part of Magnetic Resonance Imaging (MRI). The technical workforce at Filtronics consisted of design engineers, technicians in charge of the production process, and three sales engineers. The president and founder of Filtronics acted as a sales engineer, and so did the company's vice-president. A young engineer acted as the third sales engineer.

Our informants at Filtronics classified their sales projects into two types: 'standard' and 'customized'. All the products offered by Filtronics originated out of customized projects, which were developed according to a specific customer application. These clients were Fortune 500 firms, serving as 'lead users' (Von Hippel 1988). It was not uncommon for the customer's system to exist only as a set of schematics and block diagrams. Once a filter was customized, Filtronics strove to sell it off the shelf as a 'standard' product to other companies designing similar applications.

Research Design and Methods

This study was designed as a comparative examination of two seller-buyer networks in markets with distinctively different knowledge structures. We used the 'key parameter' design (Barley and Kunda 2001: 85), which enabled us to compare and contrast the structure and content of seller-buyer networks along central dimensions such as level of knowledge asymmetry and the types of knowledge being transferred. This design allowed us to examine the impact of the structure of knowledge on relational patterns in a market for emergent technologies and in a mass market for more standard products.

The first author conducted in-depth interviews with Filtronics's sales engineers. During a joint lunch meeting the sales engineers were asked to specify the most standard and the most customized projects they had worked on. They mentioned two projects on which we decided to focus. The clients for both the standard and the customized filters were very large firms, employing thousands of workers. The customized project involved the sale and adaptation of an electronics filter designed to fit into an innovative Magnetic Resonance Imaging system. This was the first time a filter manufactured by Filtronics was being put to this specific use. The more standard project involved the sale of an electronic filter that fits into a testing system for noise generated by motorcycle engines, which was part of quality control. Filtronics filters had been used as part of such testing systems in the past, and the customer approached Filtronics on the basis of the recommendation of a company already using a Filtronics filter as part of its testing system.

The firm's president granted the first author access to the company's sales files. But he allowed him to spend no more than three working days at the company, since he was concerned about the researcher's presence disrupting work. The first author was also prevented from using the Xerox machine, and had to take handwritten notes. The sales files included formal correspondence on the sales process of Filtronics products, and were organized according to specific projects, which bore the names of the prospective clients. Each of the files included internal correspondence among Filtronics employees, as well as all the correspondence between Filtronics and the client's agents, such as purchasing agents, engineers, and managers. Correspondence between Filtronics and sales representatives who initiated the transactions were also included in the sales files. Some phone calls among exchange partners were documented as handwritten notes or as printed memos in the sales files. The internal correspondence on the buyer's side was obviously missing from the sales files.

Data from the sales files were collected during two phases. To collect the network data, the first author reviewed the project files of the customized and the standard projects. With each exchange of messages in the files he noted who wrote to whom. All actors who generated or received correspondence were designated actors in the seller-buyer network. Next, project files were used to create an adjacency matrix for each of the projects, which mapped the existence and the course of the direct and indirect communication paths within each of the seller-buyer networks.

In the second phase of data collection, the first author documented the content of correspondence in each of the sales files. Given the limited time frame, he sampled only about 25 percent of the correspondence in each file by the order of appearance. In the case of the seller-buyer network of the standard product, the first 25 messages in the file were sampled, while in the seller-buyer network of the customized product the first 78 were sampled. A coding scheme was applied in the course of reading the items in the sample, in an attempt to operationalize the transfer of codified versus contextual knowledge. First, as indicators for the need to transfer codified knowledge, all instances in the two sales files in which issues regarding price, product quality, or product characteristics that appeared in schematics and formal documents were recorded. Second, all instances in which face-to-face interactions and problems associated with the interpretation of formal documents were recorded. According to the literature, they constitute the best indicators for the need to communicate contextual knowledge. The interviews were used to examine empirically the degree to which contextual or codified knowledge was communicated over the two networks. The interviews also assisted in describing the exchange behavior and the nature of microlevel ties in the two networks.

Results

We first set out to examine two related hypotheses. Hypothesis 1 states that contextual knowledge, rather than codified as in a mass market, will be communicated over the seller-buyer network of emergent technology.

Hypothesis 2 states that in the exchange of emergent technology, contextual knowledge will be communicated bi-directionally, coupled with quasi-firm arrangements such as co-development and shared practice. We expected to find no transfer of contextual knowledge in the seller-buyer network of the more standard filter, and no features of 'quasi-firm' arrangements (Eccles 1985). Table 1 presents key examples of the correspondence and interview material across the two networks.

Table 1
An Analysis of the Correspondence in Seller-Buyer Networks in a Standard and a Customized Sales Project

	Standard Project	Customized Project
Indicators for type of knowledge being transferred	1. Codified knowledge which is administrative in nature, including price signalling:	2. Contextual knowledge:
	Key example 1a: **a letter from the Filtronics comptroller to the head of the project on the client's side:** 'If you wanted to change your present rental agreement to purchase the equipment after renting the equipment for a continuous period, section 8 of the rental agreement would have to be changed.'	*Key example 2a:* **from the client's design engineer to Filtronics sales engineers, indicating problems with transferring and interpreting codified knowledge:** 'What is the format for the serial command input to the VART and what is the list of VART commands and functions? We have several versions of your documents here and we find a few discrepancies between them.'
	Key example 1b: **a letter from the Filtronics vice-president to the client's head of engineering:** 'Your two months lease expires October 5. If you need the equipment a little longer, the lease provides a per diem charge.'	*Key example 2b:* **an interview with the Filtronics sales engineer:** 'You try and sit down with him [the client's design engineer], you go back and then you send him what you think you can do. Then we will meet again and we will do some paper designs or suggestions, and then he will say "well, can you do this?" This might evolve.'
Type of product development	3. Sequential development:	4. Co-development:
	Key example 3a: **a letter from the Filtronics comptroller to the head of the project on the client's side:** 'Enclosed is a quotation for a filter system as if purchased. My understanding is you will lease the system for a minimum two months period, but wish to delay purchase until no later than Feb. 1, 1995.'	*Key example 4a:* **an inside memo summarizing a discussion with the client's design engineers:** 'On our schematic u/6 pin 14 and 15 should be swapped. They made a mistake on their schematic.'
	Key example 3b: **a letter from the head of engineering in Filtronics to the client's head of project:** 'Filtronics is pleased to provide the following price quotations …The two quotations differ primarily in the frequency resolution offered.'	*Key example 4b:* **handwritten note stapled to a hand-drawn block diagram from the client's project manager to the Filtronics sales engineer:** 'Bob, this [the block diagram] may shed some light on the y-7 to 1-z cabinet changes.'

As key example 1a in Table 1 demonstrates, mainly codified and administrative knowledge was communicated among actors in the seller-buyer network of the standard filter. The correspondence included reference to clauses in the sales or rental agreement, to specific part numbers, and to price quotes (see also key example 1b). We found no evidence for attempts to communicate knowledge that was rooted in engineering practice. Codified knowledge was easy to articulate and to circulate among actors by means of notes, fax machines, formal forms and letters, and strict protocols during telephone interactions that were documented as inside memos. We found no indications of face-to-face meetings between sellers and buyers, other than a meeting at a trade show that initiated the sales process. Nor did we find any evidence of problems experienced by network actors in comprehending and interpreting the codified information they exchanged. Key example 2a, by contrast, demonstrates that actors in the seller-buyer network of emergent technology could not rely only on the transfer of codified knowledge. Formal letters, drawings, and forms did not suffice, and actors needed constantly to ask questions regarding the meaning of sketches and block diagrams. The customized filter, according to our informants, had to be integrated into the MRI system, and different graphic representations and electronic parts had to go back and forth among network actors and kept evolving over time. The interpretation of the blueprints and other documents posed a real challenge for network actors. In our analysis of the correspondence among actors of the emergent technology network, we found evidence of four meetings between Filtronics's engineers and the client's engineers. Based on the interview material, meetings took place regularly, about once a month, and lasted up to a week. Key example 2b illustrates that co-development and interactive bridging of the knowledge gap occurred during the frequent sales visits. During the meetings, our informants engaged in a technological dialogue (Pacey 1992) and communicated practice-based knowledge, and worked side by side. As expected, face-to-face meetings and co-development did not take place among network actors of the standard filter.

The content of correspondence in the two networks also reveals sharp differences in the type of product development. Sequential development characterized the sales of the standard filter. By contrast, co-development was the dominant form of activity in the network of the customized filter. Key examples 3a and 3b demonstrate that the standard filter could be quoted, sold, or leased to prospective buyers with no need to engage in shared practice or other forms of face-to-face interaction. By contrast, key examples 4a and 4b demonstrate that the customized filter was developed interactively and involved shared practice and co-development. The strongest indication, however, of the emergence of a temporary work unit in emergent technology networks, composed of members of different organizations engaged in co-development, appeared in the interview material.

Our interviews yielded more evidence of intense face-to-face interactions with several of the client's engineers from the initial stages of the sales process. No such interactions took place in the case of the network of the standard filter. A Filtronics sales engineer explained why face-to-face interactions were essential in the sales of emergent technology:

'You want to meet with them and sit face-to-face. Because often you get more information spending some time with them, whereas on the telephone the interaction takes place as long as it makes sense. Sometimes you are taking notes [while talking on the phone], but you can't really remember all the questions you should ask until later and then you have to call back.'

The face-to-face interactions allowed the bi-directional and interactive exchange of knowledge rooted in practice. During these interactions the seller's sales engineers and the client's design and test engineers exchanged blueprints and product specifications. More important, they often worked side by side on paper designs, and engaged in an intense technological dialogue regarding the specifications for the product being exchanged and its desired application. For example, it was not unusual for the seller's and the client's engineers to design part of the filter or the application together. Another Filtronics sales engineer described the sale process of the filter for the MRI system:

'Actually, with the MRI project we did all kinds of filter characteristics and we tried to meet their requirements. And as soon as they began to get answers, so they began to ask the questions: "Can I do this, can I do that this way...?" The designer started out with one spec [product specifications] but he ended up with something quite different.'

As this excerpt demonstrates, Filtronics's sales engineers and the client's design and test engineers engaged in co-development. They wrote code and revised blueprints together. Jointly, they constructed a distinct work unit composed of actors from different organizations. Occupational norms provided the normative basis for the ongoing cooperation among actors in the seller-buyer network of the emergent technology. The product and its application, which they designed together, evolved over time. The end-product developed by the new work unit was different from both the seller's and the buyer's preliminary expectations.

Our third hypothesis states that both buyers and sellers of emergent technology will engage in an intensive information search. In the seller-buyer network of the standard filter, we expected to witness an extensive information search conducted by buyers only, and centering on quality and price. The correspondence in the sales files and the interview material indicate that indeed both sellers and buyers of emergent technology engaged in an intensive information search. Filtronics sales engineers involved in the sale of the customized filter initiated visits to the client with the explicit intention of gaining in-depth understanding of the application. These visits, according to our informants, included a series of meetings with the design team, in which the sales engineers engaged in questioning of the client's designers. Typically, the head of the client's design team introduced to the sales engineers the members of the design team, and indicated which part of the application each of them had been working on. The sales engineers wrote this information down, and at the end of the meetings approached the team members and engaged in long conversations with them. The aim of these discussions, according to the sales engineers, was to identify the best 'informants' or 'technical contacts' in the design team. Sales engineers tried to identify the client's engineers who had intimate knowledge of subsections of the application that were most relevant for the adaptation process.

We also found evidence of an intensive information search conducted by the buyers of emergent technology. For example, the sales file of the customized filter included the documentation of a visit to Filtronics initiated by the client, with the intention of inspecting the production facilities and going over Filtronics's books. The whole visit was designed to help the client mitigate the uncertainty regarding product quality and production costs, and to ensure the financial viability of the supplier. In addition, the client demanded regular reports of tests conducted by Filtronics engineers on subsections of the customized filter. For example, a letter from a sales engineer to a client's design engineer opens, 'Enclosed is a summary report of the inspection of the unit which was subjected to halt test.' Other documents in the sales files demonstrate that the client's engineers expressed a deep interest in the development of the customized filter.

The sales files contain no indication of an extensive information search by buyers of the standard filter. Specifically, we found no mention of other price quotes or any reference to Filtronics's competitors. From the interviews with the sales engineers we knew that the client had approached Filtronics on the basis of the recommendation of a company already using a filter as part of its testing system. But an extensive information search might have taken place prior to the construction of the seller-buyer network we studied. In the absence of interview material with the client's engineers and administrators, we cannot verify the existence of an extensive information search in the seller-buyer network of the standard filter.

In support of hypothesis 4, the seller-buyer network of emergent technology indeed proved larger and more heterogeneous in terms of occupational membership than the network of the standard filter. The number of network actors directly involved in the exchange of the standard filter was only 10, as compared with 22 actors in the seller-buyer network of the customized filter. Administrator, head of engineering, inventory manager, and sales engineers were the occupations represented in the sales network of the standard filter. By contrast, the seller-buyer network for the customized filter was more heterogeneous; it included administrators, managers, head of engineering, design and test engineers, and a contract administrator. The total number of messages was much larger in the seller-buyer network in the high-tech market. The total volume of correspondence across the seller-buyer network in the standard market was only 107 messages, compared with 320 messages communicated across the network in the market for emergent technology.

Hypothesis 5a concerns the identity of the most central actors in each of the two networks. It suggests that experts will occupy a more central position in the seller-buyer network of emergent technology than in the network of the more standard filter. According to the research literature, there are several ways to identify the actors who hold the most central positions in any given network. A few examples are the degree, closeness, and betweenness centrality measures (Freeman 1979). The data collected from the sales files were directed data, which means that based on the sales files we could determine not only the existence of a communication path, but also the direction of communication, by noting who wrote to whom. The degree of centrality procedure is most apt for analysis of this kind of data, as it allows one to measure a network actor's potential to generate as well as receive communications. This operationalization is particularly suitable for estimating the quality of direct access to resources shared with others (Borgatti et al. 1998).

In the case of the two seller-buyer networks, the out-degree score measures the degree to which a network actor has generated communications in the network. The in-degree score measures the degree to which a network actor has received communications in a network. The results of the analysis of the two seller-buyer networks are presented in Table 2. This table specifies which network actors scored highest for in-degree and out-degree in each of the two seller-buyer networks. Table 2 contains network indices, obtained from the UCINET V network analytic program (Borgatti and Everett 1997), concerning only the three network actors who scored highest on the degree of centrality measure in each of the two seller-buyer networks. The actor found to be most central in the network was ranked 1. When network actors scored the same on either the in-degree or out-degree centrality measure, we entered them all in the same box. Table 2 also specifies whether the actors holding the most central positions worked for the seller's or client's organization. This information appears in parentheses under the occupational affiliation of the network actor.

Table 2 presents findings that strongly support hypothesis 5a. Technical experts, in our case design and sales engineers, held the most central positions in the seller-buyer network of the customized, rather than the standardized electronic filter. All but one of the most central actors in the seller-buyer network for the customized product held formal engineering degrees. The exception was the founder of Filtronics, who held a Ph.D. in mathematics and acted as a sales engineer as well the company's president. But while lacking a formal engineering degree, the firm's founder had extensive hands-on experience in designing most Filtronics products. Contract administrators and the comptroller played only an ancillary role in generating communication activities in the seller-buyer network for the customized filter. By contrast, administrators held central positions in the network of the standard filter. While engineers did take part in the sales process of the standard filter, many of the seller-buyer network actors holding central positions, such as the comptroller, the contract administrator, and even the inventory manager and the independent sales representative, had few or no technical skills.

Two of the client's design engineers held central positions in the seller-buyer network of the customized filter. They scored high on in-degree rather than on out-degree, which means they were recipients rather than initiators of communication activities in their network. The question remains as to why network actors on both the seller and the client side needed to initiate communication with the client's design engineers. One possible answer is that the customized filter was supposed to become a part of an MRI system that was still in the design stages. Not only was this a new application for a

Table 2
Relative Rank in Degree of Centrality Scores in Seller-Buyer Networks in a Standard and a Customized Sales Project

Rank	In-degree	Out-degree
Standard Project (Network Centralization Index: 39%)		
1	Engineer in charge of project (customer) (Centrality score: 44.44)	Comptroller (seller); head of engineering (seller); contract administrator (seller); sales engineer and vice-president (seller) (Centrality score: 22.22)
2	Independent sales representative (Centrality score: 33.33)	
3	Comptroller; inventory manager; head of engineering (all sellers) (Centrality score: 11.11)	
Customized Project (Network Centralization Index: 62.4%)		
1	President and sales engineer (seller) (Centrality score: 19.05)	President and sales engineer (seller) (Centrality score: 52.38)
2	Engineer in charge of project (customer) (Centrality score: 14.29)	Head of engineering department (seller) (Centality score: 19.05)
3	Two design engineers (customer). A sales engineer and vice-president (seller) (Centrality score: 9.52)	Sales engineer (seller) (Centrality score: 9.52)

Filtronics filter, but the specifications of the MRI system were still in the making, a situation that required sales engineers engaged in customization to pay close attention to design changes made by the client's design engineers. A related explanation is that the sales engineers needed to acquire contextual knowledge related to the client's desired application. Because the client's design engineers acquired contextual knowledge of the specific application through the design process, sales engineers needed to interact directly with them.

Hypothesis 5b states that the seller-buyer network will be more hierarchical in the emergent technology market, where contextual knowledge is communicated. Network hierarchy is defined by the degree to which the flow of activity in a network is unequal, forming a core of active actors, with a periphery of less active actors (Freeman 1979; Wasserman and Faust 1995: 178). To test hierarchical differences, we compared the network centralization scores of the two networks. Clear differences in network concentration between the two sales projects emerge. The network centralization index for the standard project was 39.0 percent, compared with 62.4 percent for the customized project (see Table 2). Thus, the network in the emergent technology market had greater inequality in the distribution of power. Stated differently, more power stemming from central positions was concentrated in the hands of fewer actors in the market for emergent technologies than in the more standard market.

Discussion and Conclusions

Our main argument is that markets for emergent technology have a unique structure of knowledge, as compared with more standard markets. First, products being exchanged enjoy an interpretive flexibility (Pinch and Bijker 1987). Second, contextual knowledge needs to be communicated in markets for emergent technologies to close a deal, as opposed to articulated knowledge, which is typically sufficient to complete a transaction in a mass market. We maintain that this unique knowledge structure impacts microlevel ties and the coordination mechanisms in markets for emergent technology. To test our argument we compared a seller-buyer network in a standard and an emergent technology market.

Content analysis reveals that contextual knowledge was crucial for the customization process and that the seller's technical experts developed a technological dialogue and engaged in co-development with the client's experts. Co-development involved frequent face-to-face interactions, the sharing and replication of experiential knowledge, and the development of shared interpretations of product application. The trust in experts' competence within the emergent technology network enabled the actors to activate their tacit experience, to judge novel situations, to share heuristics and rules of thumb, and to construct a production-floor knowledge stream. Our findings indicate that technological dialogue is part of a unique search behavior in emergent technology markets. Here, both buyers and sellers engage in an intensive information search. For sellers, the feasibility of the client's application is a major source of uncertainty, while buyers invest their efforts in assessing product quality and production costs.

The seller-buyer network in the emergent technology market was shown to be more heterogeneous in occupational terms, more concentrated, and more hierarchical, with experts located at the center of the communication network, than in the network of the standard filter. By contrast, the seller-buyer network of the standard filter was more homogeneous, sparser, and less hierarchical, with administrators rather than technical experts located at the center of communication. The high centrality of technical experts in the emergent technology network also allowed network actors, as an emerging work unit, to communicate the contextual knowledge needed for the construction of a common image of the product being co-developed. The analysis of communication in the network of the standard filter did not detect signs of co-development, and we discovered no indications of a technological dialogue across the network. Instead, faceless relationships and sequential development typified the activities of actors in the network of the more standard filter.

This exploratory study does demonstrate the potential of empirical investigation of seller-buyer networks as a building block of virtual, temporary, or even kaleidoscopic vertical integration. The dichotomized view of hierarchy versus market portrayed by transaction cost theory (Williamson 1985) was corrected by the network organization, as described by network theorists (for example, Borgatti 1997; Jones et al. 1997; Miles and Snow 1994; Powell 1990). In contrast to both approaches, we point to another structural possibility: quasi-vertical temporary integration through the existence and maintenance of ephemeral, yet intensive, cross-firm expert ties. These ties are governed by professional norms and practice, and are maintained as long as a project lasts. Still, these ties are stratified to a greater extent than the standard network, with technical experts holding the most powerful positions. Given their relatively short life span, these quasi-vertical integration structures cannot be fully transformed into complete vertical integration or joint ventures (Kogut 1988).

Economists tend to extend their atomistic and rational model of markets from consumer to industrial markets, and deem seller-buyer networks ephemeral and lacking social structure. Our findings support a radically different model of seller-buyer networks, focusing on the social embeddedness of economic activity (Granovetter 1985; Uzzi 1997). This model suggests that the specific membership base of seller-buyer networks will be more robust, and will be activated more frequently with substantial levels of social cohesiveness, than economic theory holds.

Few would contest the claim that members of organizations or occupational communities share goals, values, and some form of a consciousness of kind (Freidson 1973; Van Maanen and Barley 1984). However, considering our findings, do actors in quasi-vertical integration structures in markets for emergent technology exhibit social cohesiveness in the form of shared goals and a consciousness of kind? To what extent do actors in seller-buyer networks develop mutual interests that are distinct from their organizational or occupational interests? How do different structures of quasi-firms impact actors' behavior? These questions, emerging directly from our study, remain to be empirically tested.

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