Strategic Management Journal
Strat. Mgmt. J., **21**: 345–367 (2000)

CREATING AND MANAGING A HIGH-PERFORMANCE KNOWLEDGE-SHARING NETWORK: THE TOYOTA CASE

JEFFREY H. DYER[1]* and KENTARO NOBEOKA[2]
[1]*Marriott School of Management, Brigham Young University, Provo, Utah, U.S.A.*
[2]*Research Institute for Economics and Business Administration, Kobe University, Kobe, Japan*

Previous research suggests that knowledge diffusion occurs more quickly within Toyota's production network than in competing automaker networks. In this paper we examine the 'black box' of knowledge sharing within Toyota's network and demonstrate that Toyota's ability to effectively create and manage network-level knowledge-sharing processes *at least partially explains the relative productivity advantages enjoyed by Toyota and its suppliers. We provide evidence that suppliers do learn more quickly after participating in Toyota's knowledge-sharing network. Toyota's network has solved three fundamental dilemmas with regard to knowledge sharing by devising methods to (1) motivate members to participate and openly share valuable knowledge (while preventing undesirable spillovers to competitors), (2) prevent free riders, and (3) reduce the costs associated with finding and accessing different types of valuable knowledge. Toyota has done this by creating a strong* network identity *with rules for participation and entry into the network. Most importantly,* production knowledge is viewed as the property of the network. *Toyota's highly interconnected, strong tie network has established a variety of institutionalized routines that facilitate multidirectional knowledge flows among suppliers. Our study suggests that the notion of a dynamic learning capability that creates competitive advantage needs to be extended beyond firm boundaries. Indeed, if the network can create a strong identity and coordinating rules, then it will be superior to a firm as an organizational form at creating and recombining knowledge due to the diversity of knowledge that resides within a network.* Copyright © 2000 John Wiley & Sons, Ltd.

> The ideas behind the Toyota Production System have basically diffused and are understood by our competitors. But the know-how regarding how to implement it in specific factories and contexts has not. I believe that Toyota Group companies are better at implementing the ongoing *kaizen* activities associated with the Toyota Production system . . . I think we are better at learning. (Michio Tanaka, General Manager of International Purchasing, Toyota Corp., June 10, 1996)

Recently both executives and academics have identified organizational learning as perhaps *the* key factor in achieving sustainable competitive advantage. Indeed, the academic literature on organizational learning as a source of competitive advantage has been expanding in unprecedented fashion (Cohen and Levinthal, 1990; Teece, Pisano, and Shuen, 1997; Kogut and Zander, 1992; Spender, 1996; Grant, 1996). For example, Teece *et al.* (1997) have proposed a 'dynamic capabilities' approach to firm-level advantage suggesting that a firm's ability to continually learn, adapt, and upgrade its capabilities is key to competitive success. Other scholars have argued for a 'knowledge-based view of the firm' suggesting that the key role of the firm is in creating, storing, and applying knowledge (Kogut and Zander, 1992; Conner and Prahalad, 1996; Grant, 1996) rather

Key words: knowledge management; learning; networks
*Correspondence to: Professor J. Dyer, Marriott School of Management, Brigham Young University, 790 Tanner Building, Provo, UT 84602, U.S.A.

CCC 0143–2095/2000/030345–23 $17.50
Copyright © 2000 John Wiley & Sons, Ltd.

than simply reducing transaction costs (Coase, 1937; Williamson, 1985).

Although the focus of the organizational learning literature is on the individual firm, there is increasing evidence which suggests that a 'network' of firms may be a critical, but less understood, unit of analysis for understanding firm-level learning (Powell, Koput, and Smith-Doerr, 1996; Dyer and Singh, 1998). Various scholars have recognized that *inter*-organizational learning is critical to competitive success, noting that organizations learn by collaborating with other firms as well as by observing and importing their practices (March and Simon, 1958: 188; Powell *et al.*, 1996; Levinson and Asahi, 1996). For example, von Hippel (1988) found that a firm's customers and suppliers were its primary sources of innovative ideas. He argues that a production network with superior knowledge transfer mechanisms among users, suppliers, and manufacturers will be able to 'out-innovate' networks with less effective knowledge-sharing routines.

In a similar vein, Powell *et al.* (1996) found that in the biotechnology industry the locus of innovation was the network, not the individual firm. Patents were typically filed by a large number of individuals working for different organizations, including biotech firms, pharmaceutical companies, and universities. Powell *et al.* (1996) argue that biotech firms who are unable to create (or position themselves in) 'learning networks' are at a competitive disadvantage. Although Powell *et al.* (1996) make the case for the 'network' as the appropriate unit of analysis for learning and innovation in biotechnology, they do not address the specific routines involved in the inter-organizational learning process.

In fact, although there has been considerable theoretical discussion on organizational and network learning, there is little empirical research to date. As Grant (1996: 384) recently observed, 'detailed study of the operation of organizational [learning] routines is limited. Further progress is critically dependent upon closer observation of the processes through which tacit knowledge is transferred.' How exactly are learning networks created? What are the structures and processes that allow for effective interorganizational learning? How do networks solve problems inherent in knowledge sharing, such as free rider problems and preventing undesirable spillovers? To answer these questions, we must empirically examine those networks that have demonstrated a particular ability at knowledge transfers.

The automotive industry offers an interesting opportunity to examine interorganizational learning. Automobiles are developed and manufactured by OEMs and their supplier networks, who produce as much as 70 percent of the value of a vehicle. Consequently, the cost and quality of a vehicle are a function of the productivity of a network of firms working in collaboration. Research to date suggests that Japanese automotive networks, and Toyota's in particular, have been superior at transferring productivity-enhancing knowledge throughout the network (Nishiguchi, 1994; Lieberman, 1994; Lieberman and Asaba, 1997). For example, Lieberman and Asaba (1997) examined the diffusion of lean production practices as measured by labor productivity improvements and inventory reductions by automakers and their suppliers from 1965 to 1990. They found that in Japan labor productivity (as measured by value added per employee) increased steadily and consistently for both automakers and suppliers throughout the time period (see Figure 1; we have added data on Toyota). In contrast, the productivity of U.S. automakers and suppliers was stagnant until the mid-1980s when U.S. automaker productivity began to increase. These productivity increases began when Japanese automakers began establishing transplants in the United States (U.S. figures include transplants) and when U.S. automakers were seriously attempting to imitate 'lean' production practices. However, these productivity improvements did not spillover to U.S. suppliers, whose productivity remained stagnant until roughly 1990.[1] Why is this the case?

We submit that the answer has to do with the fact that Toyota and other leading Japanese automakers (notably Honda) have developed bilateral and multilateral knowledge-sharing routines with suppliers that result in superior inter-organizational or network-level learning. Toyota, in particular, is widely recognized as a leader in continuous learning and improvement. There are a number of reasons to examine Toyota's practices in greater detail. First, Toyota is the

[1]Lieberman and Asaba's analysis on inventory reductions over time mirror the labor productivity data. Moreover, Sako (1997) replicated Lieberman's study in the United Kingdom with virtually identical results.

Copyright © 2000 John Wiley & Sons, Ltd.

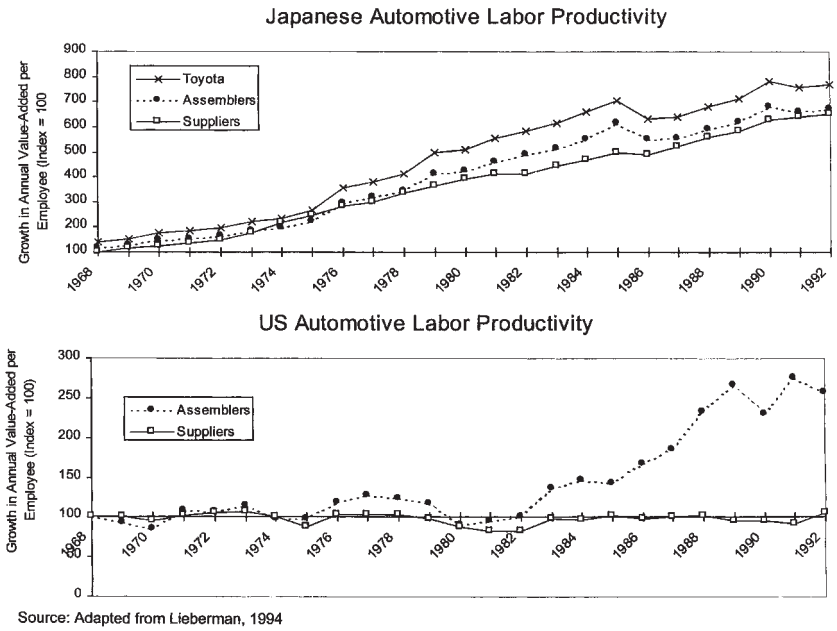

Figure 1. Japanese and US labor productivity (1968-1992)

largest Japanese company and is regularly voted by Japanese executives as the best-managed and the most respected Japanese company. Second, the most rapid diffusion of lean production techniques (e.g., kanban, inventory reduction) has occurred within Toyota and its suppliers. Lieberman *et al.* (1997) found a significant positive correlation between membership in Toyota's supplier association and supplier productivity. In summary, Toyota's 'network' appears to be highly effective at facilitating interfirm knowledge transfers and may be a model for the future. However, at present the collaborative process used by Toyota to facilitate these transfers is somewhat of a black box.

This exploratory case study has two primary objectives. The first objective is to examine in detail the institutionalized knowledge-sharing routines developed by Toyota and its suppliers. We also examine how Toyota has addressed the fundamental dilemmas associated with knowledge transfers in a network setting (e.g., free rider problems). Second, since Toyota is early in the process of creating a learning network with U.S. suppliers, we have the opportunity to examine how a firm establishes a new knowledge-sharing 'network.' Thus, we examine the creation and evolution of Toyota's U.S. supplier network.

THEORETICAL BACKGROUND

Previous research suggests that organizations that are effective at 'learning' have developed routines that allow them to effectively develop, store, and apply new knowledge on a systematic basis (Nelson and Winter, 1982; Levitt and March, 1988; Cohen and Levinthal, 1990; Nonaka, 1994). Nelson and Winter (1982) were among the first to argue that organizational 'routines' are the essence of the firm and that organizational learning would be expected to occur when firms develop 'adaptation routines' that allow the firm to modify existing routines based upon new knowledge. Other scholars have also viewed organizational learning as 'routine based and history dependent' (Levitt and March, 1988: 319). Following Grant (1996) we define a learning routine as *a regular pattern of interactions among individuals that permits the transfer, recombination, or creation of specialized knowledge*. Collectively, these routines may be viewed as a capability at managing knowledge flows in interfirm networks (Lorenzoni and Lipparini, 1999). Of course, organizational learning may also be haphazard in the sense that knowledge is not generated by routines but rather is based on 'luck' or haphazard events. In this study we are interested in studying 'routine-based' learning

Copyright © 2000 John Wiley & Sons, Ltd.

rather than 'haphazard' learning. Our objective is to examine learning that is facilitated through interorganizational routines that are *purposefully designed to facilitate knowledge transfers* across organizational boundaries.

We are interested in the 'production network' as the unit of analysis rather than the individual firm (although these two levels of analysis are clearly related). Consequently, the routines of interest are those collectively developed within Toyota's production network that are designed to facilitate knowledge transfers among network members. Since our focal interest is knowledge sharing, it is useful to define what we mean by knowledge. Most scholars divide knowledge into two types: (1) *explicit knowledge or information*, and (2) *tacit knowledge or know-how* (Kogut and Zander, 1992; Grant, 1996; Ryle, 1984). Information is defined as easily codifiable knowledge that can be transmitted 'without loss of integrity once the syntactical rules required for deciphering it are known. Information includes facts, axiomatic propositions, and symbols' (Kogut and Zander, 1992: 386). By comparison, know-how involves knowledge that is tacit, 'sticky,' complex, and difficult to codify (Nelson and Winter, 1982; Kogut and Zander, 1992; Szulanski, 1996). The properties of know-how suggest that, compared to information, know-how is more likely to result in advantages that are sustainable (Nonaka, 1994). Our research elaborates on how the Toyota network is designed to facilitate the sharing of tacit know-how.

Previous research suggests a number of dilemmas associated with knowledge sharing (collaboration) in a network setting. The first dilemma is how to motivate self-interested network members to participate in the network and to openly share *valuable* knowledge with other network members (Wood and Gray, 1991). The natural tendency of individual firms is to protect know-how viewed as proprietary to prevent undesirable knowledge spillovers. Consequently, many firms (especially those with proprietary know-how) will be reluctant to participate in interfirm knowledge-sharing activities. This is the essence of the knowledge-based view of the firm as argued by Kogut and Zander (1992), who claim that firms exist because they are better than markets at transferring, recombining, and creating knowledge. Thus, a key challenge for a knowledge-sharing network is to motivate members to participate and contribute knowledge to the collective good. The knowledge that is *most* likely to be valuable to other firms in the network is often exactly the kind of knowledge that individual firms want to keep proprietary.

The second major dilemma is the 'collective action' or 'free rider' problem. The free rider problem is often discussed in collective action theories that examine the challenges associated with achieving collaboration toward common goals among self-interested individuals, groups, or organizations (Sandler, 1992; Marwell and Oliver, 1993). Successful collaboration may produce 'collective' or 'public' goods (e.g., knowledge) that are accessible to all members of the network. However, the creation of a public good (e.g., useful knowledge) has the potential for 'free riders,' members who enjoy the benefits of the collective good without contributing to its establishment and/or maintenance. In the case of a knowledge-sharing network, a firm may willingly participate in network knowledge-sharing activities to acquire the desired knowledge, and then exit the network or refuse to contribute its knowledge.

The third dilemma has to do with how to maximize the efficiency of knowledge transfers among a large group of individual members. It is possible for a network to create conditions that solve the first two dilemmas (members are motivated to participate and 'rules' are in place to prevent free riding), but the network may still be inefficient at knowledge sharing because it has not created the necessary pathways among members to facilitate efficient knowledge flows. By efficiency, we mean the speed and ease with which network members can find and access valuable knowledge within the network. Some types of knowledge (e.g., explicit) may be easily codified and transferred in a large group setting (e.g., through meetings), whereas other types of knowledge (e.g., tacit) require intense interaction and are likely to be successfully transferred only in a small group setting at the specific location where the knowledge is used. If the network only convenes large group meetings to share information it will likely be inefficient at transferring tacit knowledge among members. Thus, the network will likely need to create multilateral ties among members (and a variety of processes for transferring knowledge) to reduce search costs and the speed and ease with which both explicit

Copyright © 2000 John Wiley & Sons, Ltd.

and tacit knowledge is transferred among members.

In summary, a successful knowledge-sharing network must devise methods to (1) motivate members to participate and openly share valuable knowledge (while preventing undesirable spillovers to competitors), (2) prevent free riders, and (3) reduce the costs associated with finding and accessing different types of valuable knowledge.

RESEARCH METHODOLOGY

In our exploratory multimethod case study the 'network' consisted of Toyota and its group of first-tier suppliers who collaborate to develop and manufacture a motor vehicle. The automaker, Toyota, is the 'core' or nodal firm in the network because: (1) Toyota is the only firm with direct ties to every other firm in the network, and (2) Toyota is the 'convener' of the network (to use Gray's, 1989, term). As the nodal firm, Toyota not only has direct ties with each supplier, but also has some economic interdependence with each supplier. Thus, Toyota also has the most to gain from developing learning routines that increase the efficiency of the entire production network.

Interview data

The primary objective of this study was to (1) identify the *institutionalized knowledge-sharing routines* developed by Toyota and its network of first-tier suppliers, and (2) explore how Toyota's network attempts to resolve the knowledge-sharing dilemmas described in the previous section. Consequently, it was necessary to identify the organizational units (divisions) within Toyota that interact with suppliers and are involved in 'supplier development' activities. This was done by interviewing Toyota's purchasing general managers in both Japan and the United States. These senior purchasing executives identified the various Toyota divisions that had significant interactions with suppliers. These divisions included: (1) Purchasing Division, (2) Operations Management Consulting Division (OMCD), (3) Quality Assurance Division (QAD), (4) Logistics Administration Division (LAD), (5) Manufacturing Operations Division (MOD), and (6) Design Engineering Division (DED). Executives from each of these divisions were interviewed to identify the formalized routines designed to facilitate knowledge sharing with, and among, suppliers. As is appropriate in qualitative research, theoretical sampling was used (Glaser and Strauss, 1967; Strauss and Corbin, 1990). Our research team interviewed more than 30 Toyota executives totaling more than 100 hours in interviews. To verify the knowledge-sharing activities identified by Toyota, as well as explore the supplier-to-supplier routines not identified by Toyota, we also interviewed senior executives at 10 of Toyota's first-tier suppliers in Japan and 11 Toyota suppliers in the United States (see Table 1 for a list of Toyota executives and suppliers interviewed).

As we conducted interviews with both Toyota and supplier executives, we focused our attention on identifying and understanding the bilateral and multilateral knowledge transfer routines among Toyota and its suppliers. We also explored the challenges associated with the creation and maintenance of those routines.

Archival and survey data

To corroborate the data from the interviews, we gathered archival and survey data to serve as nonreactive measures of changes in practice or performance (Webb, 1981). For example, when Toyota executives and suppliers claimed that Toyota's consultants were effective at knowledge transfers to suppliers, we sought for data that would document changes in supplier performance after having received visits from Toyota's consultants. We also conducted a survey of all 97 suppliers in Toyota's U.S. supplier association and 50 of their largest first-tier Japanese suppliers to have them report on their knowledge-sharing activities with Toyota. We received responses from 39 U.S. suppliers and checked for response bias (and found none) in a follow-up survey which added nine suppliers. Thus, we received surveys from 48 U.S. suppliers (49.5% response rate). The Japanese survey, conducted with the support of the Japanese Auto Manufacturers Association (JAMA), produced 38 responses (a 76% response rate). Because of the high response rate to our surveys in both the U.S. and Japanese samples, we feel comfortable that our findings are representative of the entire population of Toyota suppliers. Whenever possible, we tried to verify

Copyright © 2000 John Wiley & Sons, Ltd.

Table 1. Totota executives and suppliers interviewed

Toyota executives interviewed

Name	Position
1. Koichiro Noguchi	Gen. Mgr.–Int. Purchasing
2. Michio Tanaka	Gen. Mgr.–Int. Purchasing
3. Junzo Matsumoto	Mgr.–Planning & Admin. Int. Purchasing Div.
4. Kenji Sato	Corp. Mgr.–Purchasing
5. Nobuhiko Suzuki	Mgr.–Cost Reduction Int. Purchasing Div.
6. Keiichi Tamura	Asst. Mgr.–Engine, Power Train, & Electronics Parts & Body Purchasing
7. Tsuyoshi Kuriyamoto	Mgr.–Metal, Interior & Chemicals, Parts & Body Purchasing
8. Bart D. Heller	N. Amer. Project Group Int. Purchasing Div.
9. Hiroshi Kawaguchi	Mgr.–Administration Purchasing Planning
10. Ichiro Yamada	Asst. Mgr.–Planning & Administration Group Int. Purchasing Div.
11. Yukihito Takemura	Asst. Mgr.–Equipment Design Dept. Body
12. Suguya Fukusato	Proj. Mgr.–Int. Affairs Technical Admin. Div.
13. Takaaki Matsumoto	Gen. Mgr.–Public Affairs
14. Noriyuki Yokouchi	V.P.–Purchasing
15. Chris Nielson	Asst. Gen. Mgr.–Purchasing Planning
16. Motoo Usui	Coord.–Purchasing
17. Lance Lewis	Mgr.–Tech. Support Purchasing Planning
18. F. E. (Gene) Tabor	Gen. Mgr.–Parts and Components Purchasing
19. Masami (Max) Suzuki	Coordinator–Purchasing
20. Tom Fitzgibbons	Asst. Project Mgr.–Tech. Support–Purchasing
21. Hajime Ohba	General Mgr., TSSC
22. Lesa Nichols	Asst. Mgr.–Research & Training, TSSC
23. Cindy Kuhlman-Voss	Specialist–Research & Training, TSSC
24. Koji Kondo	Proj.Mgr.–Bus. Planning Proj. Planning/Mgmt.
25. James R. Olson	V.P.–External Affairs
26. Kenji Miura	Manager, OMCD
27. Kazunori Hayashi	Project GM, Int. Purchasing
28. Toshihiro Sugai	Gen. Mgr., Quality Control
29. Ryoichi Hibio	Manager, Purchasing
30. Akihiko Morikawa,	Manager, Purchasing

Toyota suppliers interviewed

Japan	United States
1. Nippondenso Co.	1. Johnson Controls, Inc.
2. Kojima Press Co.	2. Continental Metal Specialty, Inc.
3. NSK Ltd.	3. Summit Polymers, Inc.
4. Asahi Glass Co.	4. Amtex
5. Aishin Seiki Co.	5. Aisin U.S.A. Mfg., Inc.
6. Araco Corporation	6. Quality Safety Systems Co.
7. Tokai Rika Co.	7. Lucas Body Systems NA–Ettrick
8. Toyota Automatic Loom Works	8. Tokai Rika U.S.A., Inc.
9. Toyota Auto Body Co.	9. Takata Inc.
10. Central Motor Wheel Co.	10. McKechnie Vehicle Components
	11. Grand Haven (GHSP)

Copyright © 2000 John Wiley & Sons, Ltd.

the interview data through archival or survey data.[2]

The processes involved in the constant comparative method were used as internal checks on the validity of the data. The constant comparative method is described well by Browning, Beyer, and Shetler (1995: 121):

> As the research proceeds and new data are collected, they are constantly being compared to prior data in terms of categories and hypotheses. When new data yield new or inconsistent information, conceptual categories and the emerging theory are modified to take them into account. This process is repeated until theoretical saturation is reached: until no new categories are emerging and no new information inconsistent with the categories and tentative hypotheses is being generated. (Glaser and Strauss, 1967; Strauss and Corbin, 1990)

The multimethod approach to data collection permitted considerable within-method and between-methods triangulation. We compared the data from interviews with the archival data. The archival and survey data could be juxtaposed to the interview data to check for potential systematic biases in the interview accounts. Discrepancies between interview data and archival data discovered in the course of the research raised questions which guided further data collection and analysis. Data collection was concluded when a level of saturation was reached (Glaser and Strauss, 1967; Burgelman, 1994). This study is subject to the general limitations of generalizability associated with field research which are well documented (see Eisenhardt, 1989).

OVERCOMING THE KNOWLEDGE-SHARING DILEMMAS: TOYOTA'S SOLUTIONS

Our exploratory study of Toyota's network suggests a number of important variables that influence the extent to which knowledge is accumulated and transferred within a vertical network. In particular, we found that Toyota was able to solve the dilemmas inherent in a knowledge-sharing network. First, to encourage suppliers to participate and openly share knowledge, Toyota has heavily subsidized the network (with knowledge and resources) during the early stages of formation to ensure that suppliers realize substantial benefits from participation (we will discuss this in greater detail when we examine how Toyota created its U.S. network). Suppliers are motivated to participate because they quickly learn that participating in the collective learning processes is vastly superior to trying to isolate their proprietary knowledge. Toyota has also introduced a number of network-level knowledge-sharing processes that have, over time, helped create a strong 'identity' for the network. Previous research on collaboration suggests that the effectiveness of collaboration increases when stakeholders 'have a shared purpose' (Wood and Gray, 1991; Gray, 1989). Toyota has effectively motivated suppliers to participate in the network by creating a set of conditions that help suppliers to strongly identify with the network.

Second, to address the free rider problem Toyota has established network rules/norms that prevent suppliers from accessing Toyota's knowledge unless they first explicitly agree to openly share knowledge with other network members. This agreement is taken seriously because Toyota has the ability to impose economic sanctions (e.g., withdraw business) on a supplier that violates the rule. Finally, to ensure that the network is efficient at tacit knowledge transfers, Toyota has created a highly interconnected, strong tie network with a variety of processes that facilitate knowledge transfers. The network has multiple pathways among members (effectively eliminating most structural holes). Toyota's strong tie network is well suited for the diffusion (exploitation) of Toyota's production know-how (e.g., the Toyota production system) as well as the existing know-how that resides within its suppliers. In the following sections we examine how Toyota has overcome the fundamental dilemmas associated with creating an effective knowledge-sharing network.

Creating a network 'identity' through network-level knowledge-sharing routines

Kogut and Zander (1992: 383) argue that 'what firms do better than markets is the sharing and transfer of the knowledge of individuals and groups within an organization.' They further

[2]Nonreactive or unobtrusive data are historical, archival data which are not influenced by the perceptions or biases of the individuals providing, or gathering, the data (Webb, 1981).

Copyright © 2000 John Wiley & Sons, Ltd.

argue that 'a firm is distinct from a market because coordination, communication, and learning are situated not only physically in locality, but also mentally in an identity . . . This shared identity does not only lower the costs of communication, but establishes explicit and tacit rules of coordination' (Kogut and Zander, 1996: 502–503). Thus, knowledge is most effectively generated, combined, and transferred by individuals who 'identify' with a larger collective. Creating an 'identity' for a collective (e.g., firm, network) means that the individual members feel a shared sense of purpose with the collective. The 'identity' of the firm is defined by the organizational boundaries which dictate who is (and who is not) a member of the organization, by shared goals and values, and by patterns of interaction among individuals that give rise to a common language and common frameworks for action (MacDuffie and Helper, 1997).

While Kogut and Zander's arguments are applicable to firms, we found that in Toyota's case they are equally applicable to networks. If a network can create a shared identity among members, then that shared identity can lower the costs of sharing knowledge within the network. Furthermore, the diversity of knowledge that resides within a network is much greater than that which resides in a single firm. Consequently, if the network can get its members to 'cooperate in a social community' it will create learning opportunities far superior to firms that do not reside within such a network.

Toyota's network is effective at knowledge sharing, in part, because a strong network 'identity' has emerged and the network has established rules (network norms) that support coordination, communication, and learning. In Japan, Toyota's network is known as the 'Toyota Group' and Toyota openly promotes a philosophy within the Toyota Group called 'coexistence and coprosperity' (*Kyoson kyoei* in Japanese). Toyota has also promoted this philosophy as a core value held by Toyota in a manual (called 'Selling to Toyota') that they created to help U.S. suppliers learn how to best work with Toyota. Stated Koichiro Noguchi, Toyota's head of international purchasing, 'We must have the best suppliers in the industry. We rely on them for our success. Quality cars require quality suppliers' (August, 1993). This sentiment was echoed by a Toyota supplier executive in Japan (from Kojima Press) who stated that 'Toyota truly believes in *kyoson kyoei*. It's not just a slogan. They are true believers.' This executive unknowingly acknowledged that his company had internalized the philosophy when he commented that, 'As a Toyota supplier, we know that our success is tied to Toyota's.'

Toyota promotes the philosophy of *kyoson kyoei* and creates a shared network identity by developing *network-level* knowledge acquisition, storage, and diffusion processes. The most important of these network-level processes are: (1) the supplier association (a network-level forum for creating a shared social community, inculcating network norms, and sharing [mostly explicit] knowledge), (2) Toyota's operations management consulting division (a network-level unit given accountability for knowledge acquisition, storage, and diffusion within the network), (3) voluntary small group learning teams (*jishuken*), or a sub-network forum for knowledge sharing that creates strong ties and a shared community among small groups of suppliers, and (4) interfirm employee transfers (some job rotations occur at the network level). These four key processes create an 'identity' for the network and also facilitate knowledge transfers among network members.[3] We examine each of these processes in greater detail.

Supplier association

Toyota's supplier association (*kyohokai*) in Japan was established in 1943 to promote 'mutual friendship' and the 'exchange of technical information' between Toyota and its parts suppliers. In 1996 Toyota's *kyohokai* had three stated 'purposes': (1) information exchange between member companies and Toyota, (2) mutual development and training among member companies, and (3) socializing events (Internal Toyota Document, 1996). To achieve these purposes, Toyota's

[3]We view the relationship between identity and collective learning processes as analogous to the relationship between interfirm (or interpersonal) trust and information sharing. Some trust (minimum threshold) is necessary for one party to share confidential information with another party. Thus, some trust is a required condition for information sharing. However, as one party begins to share information with the other party, then trust increases. This begins a relationship characterized by mutual causality. In similar fashion, we believe that identity is both a cause, and a consequence, of collective learning processes.

Copyright © 2000 John Wiley & Sons, Ltd.

kyohokai is divided into three regions: Tokai *kyohokai* (150 members) for the Tokai region (Aichi prefecture where Toyota City resides), Kanto *kyohokai* (65 members) for the Tokyo region, and Kansai *kyohokai* (29 members). Toyota has created three separate regional associations because it believes that suppliers must be in close geographic proximity to achieve the association's objectives.

Toyota's *kyohokai* has general meetings every other month (e.g., general assembly, top management meetings) that are designed to allow for high-level communication within the network with regard to production plans, policies, market trends, etc. Thus, these meetings primarily facilitate the sharing of explicit knowledge among members. More frequent interaction occurs within the association's topic committees (cost, quality, safety, etc.).

The 'topic' committees on cost, quality, safety, and general affairs are designed to facilitate knowledge sharing on topics that are critical to all members in the network.[4] The PR-Sports committee (which primarily sets up golf events and baseball activities) is designed to facilitate social interaction among members. To illustrate the role that the topic committees play in facilitating network identity and learning, we examine the quality committee activities in greater detail.

The quality committee engages in a number of activities designed to increase the amount of knowledge that resides in the network with regard to product quality. The 'regular committee' picks a theme for the year (e.g., the 1994 theme was 'Eliminating supplier design defects') and meets six times each year to share knowledge with regard to that particular theme. These themes are selected by suppliers (with Toyota's input) in areas believed to be important and relevant to a large number of members in the network. In addition to the 'regular committee' meetings, the quality committee also sponsors 'basic quality training,' 'excellent plant tours,' and an annual 'quality management conference.' The training course, which is provided by the association for both Toyota and its suppliers' engineers, offers 12 days of quality training to approximately 100 engineers each year. This training provides a basic, common knowledge base (builds absorptive capacity) among network members which allows them to more efficiently transfer more complex quality knowledge through plant tours, conferences, etc.

The excellent plant tours allow network members to visit 'best-practice' plants both inside and outside the automotive industry so that members can see first hand the processes used by firms that achieve high quality. The quality management conference is held once each year and offers Toyota suppliers the opportunity to learn from lectures delivered by experienced Toyota directors and senior managers, as well as six successful supplier cases of quality improvement: two plant managers' cases, two supervisors' cases, and two quality circles' cases. The six supplier cases are selected from case write-ups submitted to a committee panel by member companies. In 1994, 146 out of 150 Tokai Kyohokai members (98%) submitted cases to the conference.

In summary, the supplier association's primary objective is to develop ties among members and transfer explicit knowledge through multilateral knowledge transfers. The committees are designed to facilitate the transfer of both explicit and tacit knowledge. The supplier association is an important vehicle for creating an 'identity' for the Toyota production network or 'Toyota Group.' Membership in the association makes members feel like they are part of a larger collective. Toyota's attempt to replicate *kyohokai* in the United States began in 1989 when it organized the Bluegrass Automotive Manufacturers Association (BAMA).

Consulting teams/problem-solving teams

Toyota's Operations Management Consulting Division (OMCD) was established in the mid-1960s by Taiichi Ohno to help solve operational problems both at Toyota and at suppliers. OMCD is the organizational unit within Toyota assigned the responsibility to acquire, store, and diffuse valuable production knowledge that resides within Toyota's production network. OMCD currently consists of six senior and highly experienced executives (each with responsibility for two Toyota plants and approximately 10 suppliers) and about 50 consultants. OMCD facilitates knowledge sharing by providing direct 'on-site' assis-

[4]The general affairs committee focuses on activities of current interest to a broad set of members. For example, during 1994 (a recession year) the committee's 'theme' was improving the productivity of white-collar workers. This is of particular importance during a recession because Japanese firms cannot easily lay off white-collar workers.

Copyright © 2000 John Wiley & Sons, Ltd.

tance to suppliers. This typically involves sending a team of consultants to the supplier for a period of time ranging from one day to many months, depending on the nature of the problem. This assistance is 'free' to suppliers who are not charged for the consultants' time. Thus, this is a network-level resource that is accessible to all members. Our 1993 survey of 38 first-tier Toyota suppliers in Japan revealed that all suppliers in our sample had, at one time or another, been visited by Toyota personnel who assisted in improving the suppliers' operations. On average, suppliers reported receiving 4.2 visits per year and these visits lasted an average of 3.1 days.

The U.S. version of OMCD is called the Toyota Supplier Support Center (TSSC). TSSC was established in 1992 with the objective of 'assisting North American suppliers to implement their own version of TPS' (Internal Toyota document, 1995). TSSC's general manager, Hajime Ohba (formerly of OMCD) heads a staff that had grown to 20 consultants by 1997. Since 1992 TSSC has received approximately 100 requests for assistance and has entered into 53 consultation projects.

To date, Toyota has found that know-how transfers with regard to TPS are extremely difficult and time consuming because the knowledge is mostly tacit. Although the goal is to achieve success in 6 months, no project has been completed in less than 8 months and most last at least 18 months. States Mr. Ohba, 'It takes a very long time and tremendous commitment to implement the Toyota Production System. In many cases it takes a total cultural and organizational change. Many U.S. firms have management systems that contradict where you need to go.' Consequently, some of TSSC's consulting projects can be quite time and resource intensive. According to an executive at Grand Haven, 'TSSC has been providing assistance to our plant for almost three years. One consultant practically lived at our plant for a year and became part of the plant family. In fact, we even threw him a baby shower when he had his first baby.'

By November of 1996, TSSC had engaged in 31 projects with suppliers with impressive results. On average, TSSC had assisted suppliers in achieving an average inventory reduction of 75 percent and an average increase in productivity or output per labor hour of 124 percent (see Figure 2). This compares to an average inventory reduction of 8 percent, and an increase in output per worker of 6 percent during the 2-year period *before* TSSC began working with the supplier. Thus, the rate of improvement has increased dramatically, suggesting that the supplier has been learning faster since working with TSSC. These data provide evidence that TSSC's knowledge transfer processes substantially improve supplier performance.

Toyota also has a process of forming problem-solving teams designed to bring knowledge to bear in solving *emergent problems* within the

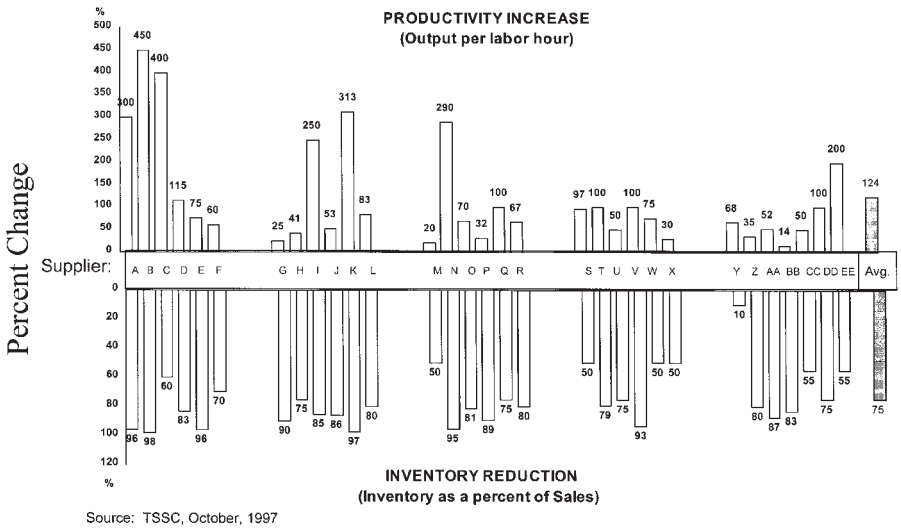

Figure 2. TSSC project results (31 suppliers)

Copyright © 2000 John Wiley & Sons, Ltd.

network. For example, a supplier may experience quality problems where the root cause is not easily determined. In this case, OMCD or Toyota's Quality Assurance Division (QAD) will set up a problem-solving team (with various Toyota divisions and possibly even other Toyota suppliers) to collectively bring their knowledge to bear to 'fix' the quality problems. When established, the team defines the root cause(s) of the supplier's quality problems and hands over the problem-solving process to an appropriate division(s) within Toyota. For example, once the problem-solving team has defined the root of the supplier's quality problem as being in product design, Toyota's Design Engineering Division (which has already been involved in the problem-solving team) will be asked to take the lead in working more closely with the supplier to implement solutions to improve quality. In some cases, Toyota may determine that the relevant knowledge resides within a competitor of the supplier. In this case, Toyota will attempt to orchestrate a supplier-to-supplier knowledge transfer.

We did not find this type of supplier-to-supplier knowledge sharing in the United States. However, eight of 10 U.S. suppliers we interviewed reported that Toyota orchestrated trips to Japan during which they visited Japanese suppliers producing the same component. As a supplier executive at Lucas Body Systems stated, 'Toyota told us to work on cutting our changeover time from 2 hours to 30 minutes. I told them it was impossible. Then they sent me to visit a Japanese supplier in our same business that had changeover times of 15 minutes. I never would have believed it if I hadn't seen it with my own eyes. My boss still doesn't believe it.'

Voluntary learning teams (jishuken/PDA core groups)

OMCD facilitates ties and knowledge sharing among suppliers in a way that is quite unique. In 1977 OMCD organized a group of roughly 55–60 of its key suppliers (providing over 80 percent of its parts in value) into 'voluntary study groups' (*Jishukenkyu-kai or jishuken*) for the purpose of assisting each other with productivity and quality improvements. Each supplier group consists of roughly five to eight suppliers, some of whom use similar production processes (e.g., stamping, welding, painting). Body suppliers are placed in one of two groups (Group I, II) and parts suppliers are placed in one of seven groups (Groups A–G). Toyota groups suppliers together based upon: (1) geographic proximity, (2) competition (direct competitors are *not* in the same group),[5] and (3) experience with Toyota (each group has at least one affiliated Toyota supplier, such as Denso or Aisin Seiki, that are expected to take a leadership role). Groups are usually reorganized every 3 years by Toyota to put some 'stimulus' into the activity and maintain diversity of ideas. Each year the suppliers meet together with the responsible OMCD manager to determine a 'theme' (project) for the year. The basic idea is to help each other increase productivity in areas of common interest. Supplier executives that participate in *jishuken* activities are typically plant managers, assistant plant managers, and/or section managers.

After a theme is decided, the group establishes a schedule to visit each supplier's plant to jointly develop suggestions for improvement. The group spends 4 months (with four phases) focused on each supplier acting as consultants to the plant. The phases are as follows: (1) preliminary inspection, (2) diagnosis and experimentation, (3) presentation, (4) follow-up/evaluation. A member of OMCD also visits frequently (i.e., every week or two) to give advice and monitor progress. This allows Toyota to bring its expertise to bear to help solve supplier problems. It also allows Toyota to 'learn' what is being learned by suppliers. This adds to Toyota's stock of knowledge and allows OMCD to keep abreast of new ideas and applications of the Toyota Production System. This is valuable to both Toyota and the network because OMCD can transfer this knowledge to Toyota's internal operations or to other suppliers. At the end of the year Toyota organizes a meeting (conference) where all of the *jishuken* groups meet together to share what they have learned from the year's activities.

In 1994 Toyota established its Plant Development Activity (PDA) core groups, which was an attempt to replicate the *jishuken* concept in the United States. Three groups were formed (using

[5]Only a small number (perhaps one to five) of suppliers in the network are viewed as direct competitors. Thus, most suppliers in the network are in a noncompetitive situation when it comes to knowledge sharing.

Copyright © 2000 John Wiley & Sons, Ltd.

the same criteria as in Japan) with 11 suppliers placed in each group. The theme for the first year was 'quality improvement' because, as Toyota's Chris Nielsen noted, 'everyone agrees that they can improve quality'. Each core group member was asked to select a 'demonstration line' within a plant as a place to experiment when implementing the concepts. A schedule was developed to meet for one day each month at a supplier plant, during which Toyota personnel from the technical support group would demonstrate some key concepts at the demonstration line, and the group members would discuss ways to improve the line. The group would visit the same supplier for 3 months and then rotate to a new supplier.

After the first year, many other suppliers wanted to participate, so Toyota added 15 suppliers and another PDA core group in 1995 (roughly 12 suppliers per group). However, some of the groups were experiencing difficulties because of markedly different skills and knowledge of TPS methods among suppliers. Stated Toyota technical support specialist Tom Fitzgibbons, 'we tried high skill and low skill suppliers together but sometimes it didn't work well because we had to keep stopping to explain basic concepts to the new suppliers. The more experienced suppliers were getting frustrated'. Consequently, Toyota reorganized the groups in 1996 into four groups where 'skill level' was also considered. The 'orange' group included suppliers with strong TPS skills, the 'blue' and 'green' groups with mid-level skills, and the 'purple' group consisted of less experienced members.

To be considered for participation in a PDA core group the supplier must be a member of BAMA for at least one year. Toyota claims that this requirement is necessary to assure assimilation into BAMA, top management commitment, and familiarity with the basic concepts of TPS. U.S. plant managers report that they believe the PDA core group activities have been extremely valuable. Stated the plant manager of Amtex,

> We get blinded just like everyone else. When you bring a whole new set of eyes into your plant you learn a lot. We've made quite a few improvements. In fact, after the (PDA) core group visits to our plant, we made more than 70 changes to the manufacturing cell. One supplier even showed us a new way to start up our equipment that was better on the machinery and saved on energy costs.

In fact, all 10 U.S. suppliers we interviewed claimed that the PDA core group activities were *more valuable* to suppliers than BAMA. The Amtex plant manager went on to say,

> I think BAMA is valuable. But the PDA core group activities are even more valuable to us than BAMA. If I had to choose, I would definitely choose to be involved in the core groups over BAMA. We learn more that is useful in our daily operations.

This comment suggests that the tacit knowledge acquired through PDA core groups is perceived to be more valuable than the mostly explicit knowledge acquired through BAMA. A key reason that the PDA core group activities are particularly effective at tacit knowledge transfers is that they involve learning that is context specific ('hands on' and 'on site'). For example, the plant manager from Kojima Press (a Japanese supplier of spoilers and body parts) described how they had acquired tacit knowledge through a jishuken project: 'The jishuken projects are very helpful. Last year we were able to reduce our paint costs by 30 percent. This was possible due to a suggestion to lower the pressure on the paint sprayer and adjust the spray trajectory, thereby wasting less paint'. Furthermore, as the plant manager at Continental Metal Specialty noted, 'We find more things that are useful visiting other suppliers' plants versus Toyota's plants. Suppliers' operations are more similar to ours'.

Like the supplier association, the learning teams help create an identity for the larger collective. As a supplier executive at McKechnie Vehicle components put it, 'We're a member of the "blue group" and we have developed good relationships with the suppliers in our group . . . So we do what we can to help other blue group members'.

Interfirm employee transfers

The practice of interfirm employee transfers (*shukko*) in Japan is by now well known (Cusumano, 1985; Lincoln, Gerlach, and Takahashi, 1992; Gerlach, 1992; Dyer and Ouchi, 1993). Some previous studies suggest that important reasons for *shukko* include helping large assemblers maintain control of suppliers and the opportunity to shed unwanted employees (Lincoln *et al.*, 1992; Gerlach, 1992). However,

Copyright © 2000 John Wiley & Sons, Ltd.

our interviews suggest that, at least in Toyota's case, *shukko* is also an important mechanism for creating a network identity and transferring knowledge from Toyota to suppliers. In our survey of 38 of Toyota's first-tier suppliers, we found that 11 percent of the suppliers' directors (*yakuin*) were former employees (the figure was 23 percent for Toyota's 'affiliated' suppliers or suppliers in which Toyota owned some stock). Overall, Toyota transfers approximately 120–130 individuals per year to other firms in the value chain, most of whom go to suppliers. Some of these transfers are permanent in nature (usually at the director level) but others are temporary. For example, when we visited Kojima Press, we found that the assistant plant manager was a Toyota engineer on leave from Toyota for a 2- to 3-year assignment. Stated the Toyota engineer, 'I am here to apply what I've learned at Toyota to help the plant manager run a more efficient plant. Also, by working at the supplier I can understand the supplier's perspective and what problems they experience'. At another supplier, we interviewed a 'transferee' who had been sent to the supplier to help it set up operations and accounting systems in the United States. This particular individual had worked in the automaker's U.S. operations and therefore had a knowledge of U.S. accounting systems which he was able to transfer to the supplier. In some cases the supplier had a need for particular skills or knowledge that members of its workforce did not possess. Consequently, it would make a request to the automaker (usually through purchasing to the personnel department) for someone with particular skills. The automaker would search within its organization and then offer someone to the supplier organization. Suppliers claimed that they had the right to refuse the person offered. However, given Toyota's importance as a customer, it is questionable as to whether this 'right' is ever exercised. Regardless, these transfers are an important routine which fulfills a knowledge transfer function. The transferred individuals not only bring particular technical knowledge with them, but more importantly they bring with them a knowledge of Toyota's personnel, systems, and technology. Thus, they know where particular expertise resides within Toyota as well as who to contact to access that expertise. Furthermore, the fact that individuals can be transferred across firm boundaries indicates that the 'unit of analysis' for a job rotation is not the individual firm, but the network. Thus, this practice further creates an identity for the network. To date, these transfers only occur with Japanese suppliers in Japan.

In summary, these four network-level knowledge-sharing processes (supplier association, consulting teams, learning teams, and employee transfers) each play an important role in creating a 'shared purpose' among suppliers and helping them believe they are part of a larger collective. These network-level learning processes facilitate frequent face-to-face interactions among suppliers and this creates a social community at the network level. Moreover, Toyota (the nodal firm) uses network-level processes to encourage and educate members to believe that they are part of an interdependent economic community. As the supplier increasingly identifies with the network, it engages in knowledge-sharing activities quite unconsciously—without any sort of cost–benefit calculus. To illustrate, when an executive at McKechnie Vehicle Components was asked why he allowed other Toyota suppliers to visit his plant and learn from his operations, he responded, 'Because they are members of our supplier association, we do what we can to help them out. We help each other because it makes us all better off'. This statement reflects the sentiment that 'what's good for the network is good for me, and what's good for me is good for the network'. Thus, the creation of a strong network identity lowers the costs of participation by members (they are less likely to engage in a cost–benefit calculus) and increases the value of participation (members are more likely to contribute valuable know-how).

Network 'rules' for knowledge protection and value appropriation

Creating a network identity was a critical first step to solving the dilemma of motivating members to participate and contribute useful knowledge to the network. However, Toyota has also established some 'rules' within the network that prevent members from both (a) protecting or hiding valuable knowledge, and (b) free riding. Toyota solves these dilemmas by simply eliminating the notion that there is 'proprietary knowledge' within certain knowledge domains (e.g., production-related knowledge). By openly sharing *all* of its production know-how, Toyota has cre-

Copyright © 2000 John Wiley & Sons, Ltd.

ated a norm (rule) within the network that very little of the knowledge that a firm possesses is proprietary (with the exception of certain product designs/technology). Production processes are simply not viewed as proprietary and Toyota accepts that some valuable knowledge will spill over to benefit competitors. Thus, any production-related knowledge that Toyota or a supplier possesses (cost, quality, inventory management, etc.) is viewed as accessible to virtually any member of the network (with *perhaps* the exception of a direct competitor) because it is, in effect, the property of the network.

Toyota creates a norm of reciprocal knowledge sharing within the production network by providing free assistance to suppliers and allowing suppliers full access to Toyota's operations and stock of knowledge. According to Koichiro Noguchi, head of international purchasing, 'Suppliers can visit any Toyota facility with the possible exception of the new model design room. We hide nothing.' But suppliers are told they *must* be willing to open their plants to other network members if they choose to receive Toyota consulting assistance and/or participate in *jishuken*/PDA core groups. States TSSC consultant Lesa Nichols, 'That's one of our requirements because if we take the time and effort to transfer the know-how, we need to be able to use the suppliers' operations as a vehicle to help other suppliers.' This requirement allows Toyota to: (1) develop some 'showcase suppliers' that have successfully implemented various elements of the TPS; this provides a valuable learning laboratory for other suppliers, and (2) get suppliers to open their operations to one another.[6] This requirement also effectively minimizes the free rider problem because the 'price of entry' into the network is a willingness to open up your operations for inspection. As a supplier executive at Summit Polymers stated, 'They gave us a gift [TPS]; how can we not open our plant and share what we've learned with other Toyota suppliers.' Thus, Toyota's willingness to freely share its valuable knowledge with other network members acts as a 'starting mechanism' (see Gouldner, 1960) for reciprocity, or more specifically for reciprocal knowledge sharing of proprietary knowledge within the network.[7] In effect, Toyota states that 'We will help you, but in return, you must agree to help the network.' The rule can be stated as follows: *The price of entry into the network is a limited ability to protect proprietary production knowledge. Intellectual property rights reside at the network, rather than firm, level*.

To date, Toyota claims that no suppliers have received Toyota's help and then refused to open their operations to other suppliers. When asked what would happen if a supplier was unwilling to open their operations to other firms in the network, one Toyota executive responded, 'that would be a serious breach of faith. Such behavior would make it difficult to give that supplier additional business.' Suppliers also seem to be aware of the possibility that Toyota could impose economic sanctions by withdrawing business. Stated an executive at Johnson Controls, 'Toyota has a certain way of working with suppliers with specific expectations. Suppliers that understand and are effective at meeting those expectations will be successful. Suppliers that don't have a hard time . . . You don't want to tell Toyota you will do something and then not do it.'

In addition to a rule that delineates property rights, the network has also established a rule that defines the timing and distribution of savings that result from knowledge transfers. Since knowledge transfers are both costly for the source, and for the recipient, of knowledge (Szulanski, 1996), the network needs some way to distribute the value realized from knowledge transfer activities. For example, Toyota makes a considerable investment in OMCD and TSSC and yet their assistance is 'free' to suppliers. If so, how does Toyota benefit from its investment? Are suppliers allowed to appropriate all of the gains? We found that when Toyota's consultants work with suppliers to transfer knowledge that results in lower costs (and higher supplier profits), it does not ask for an immediate price decrease. In fact, Toyota has intentionally separated OMCD and TSSC from the purchasing division so that suppliers can work with the

[6]Suppliers can designate certain other areas of their plants (where Toyota has not provided assistance) as off-limits to visits in order to protect proprietary knowledge.

[7]As we shall describe later, Toyota heavily subsidizes the network (with knowledge and financial resources) in the early stages of its formation to get members to participate and to establish norms around reciprocal knowledge sharing. However, as the nodal firm, over the long term Toyota receives the greatest benefits from a production network that is actively engaged in knowledge-sharing activities.

Copyright © 2000 John Wiley & Sons, Ltd.

consultants without fearing that purchasing will ask for a price decrease after the consultation. According to TSSC head Hajime Ohba, 'Our job is to help suppliers improve, not to worry about who gets the additional profits. If the supplier becomes more productive, over time we will capture some of those benefits.' Suppliers widely recognized that, at least in the short run (e.g., 1–2 years) they could appropriate 100 percent of the value from the knowledge transfers. This rule increased their incentive to participate in the network's knowledge-sharing activities. Stated a supplier executive at Amtex, 'Toyota helps you without any immediate expectations. The fact that through BAMA we have made process improvements that have saved us money and Toyota did not directly go after those savings speaks volumes. Of course, over time we must give back some of the savings in price cuts at the annual price review.' Thus, the tacit rule that has emerged around value appropriation can be summarized as follows: *The recipient of knowledge may appropriate 100 percent of the savings in the short run, but over time will be expected to share a proportion of those savings with the network (e.g., through price cuts to Toyota).*

The importance of this rule can be demonstrated by comparing the response of U.S. suppliers to receiving Toyota consultants vs. receiving General Motors consultants. Most suppliers claimed that they would willingly open their factories to Toyota consultants for two reasons. First, they believed that the Toyota consultants were experienced and possessed knowledge that could be truly valuable to their plants. Second, they trusted Toyota to offer the assistance without demanding an immediate price cut in return for cost improvements. In contrast, many General Motors suppliers indicated that they would prefer *not* to have General Motors' consultants (called PICOS teams) come to their plants. GM's 'consultants' have had a very different reception—largely because there is a different rule about value appropriation. As described by one supplier executive,

> We don't want to have a PICOS team poking around our plant. They will just find the 'low hanging fruit'—the stuff that's relatively easy to see and fix. We all have things in our plants that we know need to be fixed. They'll just come in, see it, and ask for a price decrease. We'd prefer to find it ourselves and keep all of the savings.

Stated another supplier executive,

> We allowed a PICOS team into our plant. They stayed for about a week and did make a few useful suggestions. Then we received a letter demanding a price decrease based upon the projected 'savings' from their suggestions.

Thus, even though suppliers may be able to learn something from GM, they are reluctant to accept assistance or share any information because GM's value-appropriate rule reduces the supplier's incentive to participate. The result is that GM may try to engage in knowledge transfer activities with suppliers, but suppliers are not properly motivated to participate.

Creating multiple knowledge-sharing processes and sub-networks in the larger network

The third dilemma has to do with how to maximize the efficiency of knowledge transfers among a large group of individual members. To address this problem, Toyota has established a variety of bilateral and multilateral processes, each designed to facilitate the sharing of different types of knowledge (both explicit and tacit) within the network (see Figure 3 for a summary of the key network-level routines that facilitate the sharing of different types of knowledge within Toyota's production network). Also, some processes are designed primarily for knowledge diffusion, while other processes result in both knowledge creation and diffusion. (In this context, knowledge 'creation' primarily refers to new, incremental applications of the Toyota Production System rather than the creation of innovative, breakthrough technologies.) These various processes allow for a 'matching' of the type of knowledge with a process that is the most effective and efficient at transferring that particular type of knowledge. For example, the supplier association is a vehicle for efficiently disseminating explicit knowledge (e.g., market trends, production voles) to all members of the network. In contrast, the *jishuken* groups are an effective vehicle for multilateral transfers of tacit knowledge (e.g., TPS methods, processes, philosophies) to members in the network. By creating sub-networks or 'nested networks' (e.g., the *jishuken* groups, supplier association committees) within the full network, individual members are able to develop embedded ties with

Copyright © 2000 John Wiley & Sons, Ltd.

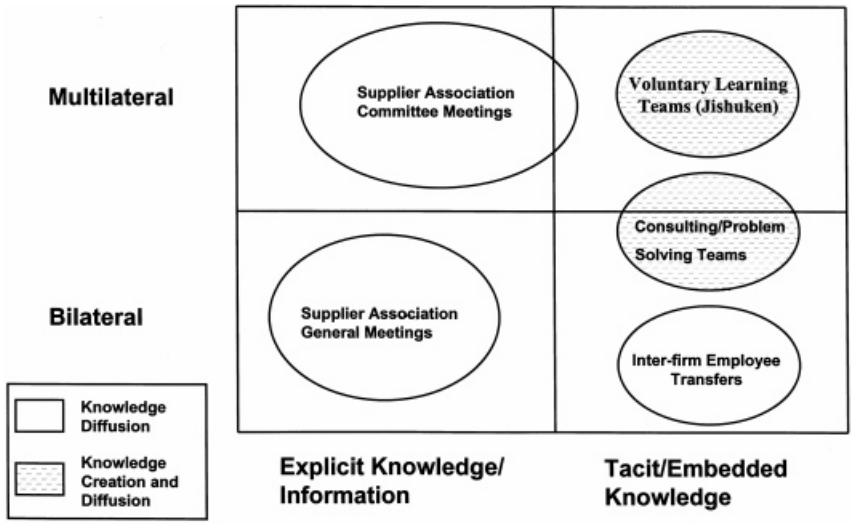

Figure 3. Toyota's network-level knowledge-sharing processes

those other members that have particularly relevant knowledge. Thus, there are a variety of processes through which members can choose to receive, or transfer, different types of knowledge. As a supplier executive at Amtex jokingly remarked, 'Do you know what TMM (Toyota Motor Manufacturing) stands for? Too Many Meetings. You just can't avoid communication. There are so many avenues, between BAMA, the PDA core groups, and personal visits.' Stated a supplier executive at Continental Metal Specialty, 'Each program serves a different purpose. BAMA is great for helping us keep abreast of what's going on in the industry and what Toyota expects from us. But for really useful ideas on how to improve your operations, the [PDA] core groups are superior.' The 'many avenues' for communicating creates a high degree of multiplicity (interconnectedness) among members in Toyota's network, thereby giving individual members a choice of medium for communicating. Further, it is not necessary for these pathways to culminate, or even intersect, with Toyota.

In summary, Toyota's network is able to efficiently transfer knowledge because there are a variety of processes available to transfer both explicit and tacit knowledge in a multilateral or bilateral setting. If the network only met in large group (i.e., supplier association) meetings, it would not be very efficient at transferring tacit knowledge. Similarly, if Toyota only provided consultants (but not the association) to engage in bilateral knowledge transfers, the network would be inefficient at transferring explicit knowledge. Thus, to maximize the speed and ease with which various types of knowledge are transferred, a variety of routines or pathways for knowledge flows is required.

THE CREATION AND EVOLUTION OF TOYOTA'S U.S. KNOWLEDGE-SHARING NETWORK

By examining the creation and evolution of Toyota's network over time, we gain insights into how a core firm (convener) may attempt to successfully create and manage a knowledge-sharing network. In particular, our longitudinal study of Toyota's relatively new U.S. supplier network offers the opportunity to examine how the network has evolved over time. Our exploratory study of Toyota suggests that three institutional innovations have played an important role in the creation of the network and in facilitating interorganizational learning. These innovations were: (1) the supplier association, (2) the knowledge transfer consultants (OMCD, TSSC), and (3) *jishuken/PDA core groups* or small-group learning teams. In both Japan and the United States, these institutions were introduced to suppliers in the same order (see Figure 4). We describe the evolution of the network as occurring in phases, from weak ties, to strong bilateral ties

Copyright © 2000 John Wiley & Sons, Ltd.

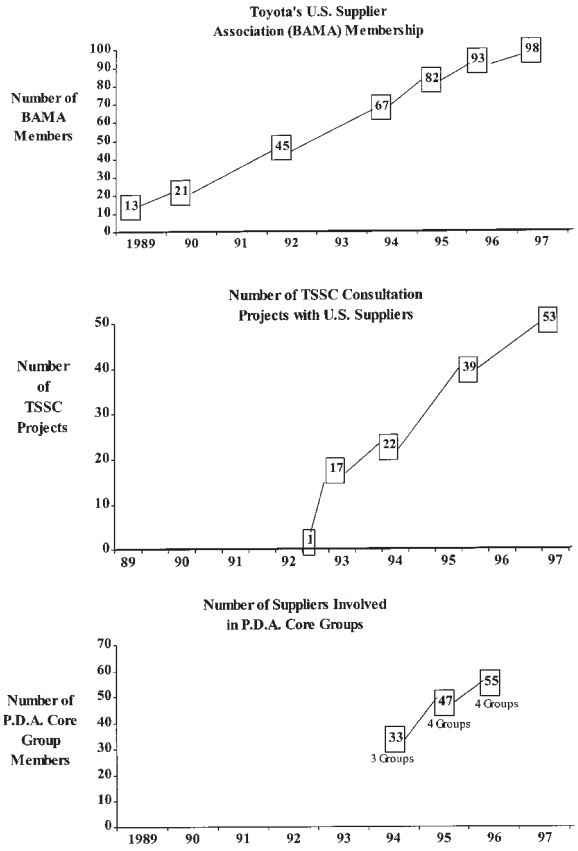

Figure 4. Evolution of Toyota's U.S. supplier network

with the convener (Toyota), to strong multilateral ties among suppliers.

Phase 1: Developing weak ties

In 1988, when Toyota first began producing cars in Georgetown, Kentucky, its suppliers did not interact with each other (and the suppliers' ties to Toyota were 'weak' in the sense that the relationships were new and the frequency and intensity of interactions was low). Knowledge sharing in the supplier network was virtually nonexistent. The first step that Toyota took to initiate knowledge sharing in the supplier network was to establish the supplier association in 1989. The supplier association facilitated the sharing of explicit knowledge (mostly unidirectional flows from Toyota to suppliers) and the creation of 'weak' social ties among suppliers. This was a critical first step in getting members of the network to talk to each other in a nonthreatening setting. Stated Toyota's Chris Nielsen, assistant general manager for purchasing planning.

> We really didn't know if this would work in the U.S. Getting suppliers to talk to each other was a key element of the program. Before BAMA, it was not very natural for supplier executives to talk and share information. It was uncomfortable. Over the years that has changed significantly as suppliers have built relationships at senior levels. (Interview, November 17, 1997)

This message was echoed by an executive at Lucas Body Systems,

> Before BAMA, we really didn't know or share information with executives at other suppliers. And we just didn't think about calling them up or visiting. It just didn't happen. BAMA has helped us to get to know each other and now it feels a lot more comfortable calling up another supplier for information or even visiting their plants. (Interview, April 18, 1997)

Thus, BAMA was the catalyst for creating weak ties among network members and it created an avenue for sharing explicit knowledge. Participation was not threatening to suppliers because they were not required to share any sensitive information or commit significant resources.

Phase 2: Developing strong ties with Toyota

Subsequent to establishing the supplier association, Toyota made its well-trained consultants available (free of charge) to transfer valuable tacit know-how regarding TPS at the suppliers' facilities. The Toyota consultants were the catalysts for creating a norm of reciprocal knowledge sharing and a feeling of indebtedness and openness within the supplier network. Indeed, to receive assistance from Toyota consultants the supplier had to agree to open up its plant to other Toyota suppliers. As the vice president of planning for Summit Polymers, a supplier of plastic interior parts, stated,

> I couldn't believe it but Toyota sent approximately 2–4 consultants *every day* for a period of 3–4 months as we attempted to implement Toyota Production System concepts in a new plant. They gave us a valuable gift [the Toyota Production System]. Naturally we feel indebted towards Toyota and view them as a special customer; they sincerely want to help us improve . . . How could we try to keep what

Copyright © 2000 John Wiley & Sons, Ltd.

> we've learned from other Toyota suppliers? (Interview, November 19, 1996)

Thus, Toyota's consulting assistance created much stronger direct ties with suppliers and was the catalyst for creating, in Gouldner's (1960) terminology, 'a norm of reciprocal obligation.' As more and more suppliers had an intensive knowledge transfer experience with Toyota's consultants (typically over a 1-to 2-year period), they became comfortable with knowledge transfer activities. They also experienced first hand the potential economic benefits associated with knowledge sharing. Moreover, an increasing number of suppliers were obligated to allow visits from other suppliers in the network.

Phase 3: Developing strong ties among suppliers

Finally, after suppliers had developed social ties and norms of reciprocal knowledge sharing with Toyota, Toyota divided suppliers into small learning teams. Toyota carefully organized the teams to maximize the willingness and ability of suppliers to learn from each other (e.g., keeping direct competitors apart; rotating group membership to maximize diversity of ideas, requiring a minimum level of absorptive capacity with regard to TPS, etc.). By doing so, Toyota created a set of 'sub-networks' within the full network. These sub-networks were designed to facilitate the creation of strong ties among suppliers, which in turn has facilitated the sharing of tacit knowledge among members. Stated the plant manager of McKechnie Vehicle Components,

> We've benefitted greatly by participating in the [PDA core] group. It is now very natural for us to share what we know with the other suppliers in our group. We know each other well and are committed to helping each other . . . I don't know that I could have imagined this sort of activity five years ago. We just didn't interact with other suppliers.

Not only have strong ties developed through the formal 'core group' activities—strong ties and avenues for knowledge sharing have also developed informally. Stated an executive at Amtex,

> We don't just visit 'core group' members. In fact, one of our most helpful visits was to Tower. We heard that Tower had one of the best kanban systems so we asked them if we could visit and see what they do. We had a very productive visit and they are coming to visit us as well.

Thus, over time the network has become increasingly interconnected with numerous redundant ties. As evidence, our sample of 48 U.S. suppliers reported that in the year *before* participating in BAMA they only visited, or were visited by, other automotive suppliers an average of 5.1 days during the year. However, after joining BAMA and the PDA core groups, they reported visiting, or being visited by, other suppliers 33.8 days per year (a $7\times$ increase in face-to-face contact, and these numbers do not include the increased face-to-face contact through BAMA). Thus, the structural holes in the network are disappearing. The result is that the network relies less on Toyota to direct and facilitate the knowledge-sharing activities. States Nielsen, 'We want our suppliers to help each other. That's the whole idea. We realize we simply don't have the resources or information to help all our suppliers as much as we'd like to.' However, while Toyota's role as an arbitrager of knowledge has diminished, Toyota's 'control' over the network-level knowledge-sharing processes (e.g., association, consultants) helps it maintain its leadership role (power and relevance) in the network. For example, the consulting division is a mechanism that allows Toyota to simultaneously 'learn' from the network (thereby giving Toyota power because Toyota possesses greater access to more leading-edge knowledge than other members) and also 'monitor' the network's activities.

In summary, the network structure, motivation for member participation, and types of knowledge shared have evolved substantially within Toyota's supplier network. In the initiation phase the network structure was essentially a collection of dyadic ties with the nodal firm (Toyota) as a hub heavily subsidizing network activities (see Figure 5). Toyota's subsidies came in two forms: (1) financial (money for meeting rooms, social activities, organizing and planning meetings); and (2) valuable knowledge (Toyota invested in TSSC and would send its consultants free of charge to participating members). It was important for Toyota to subsidize network knowledge-sharing activities early on to motivate members to participate and to ensure that they realized sufficient benefits from participation.

Copyright © 2000 John Wiley & Sons, Ltd.

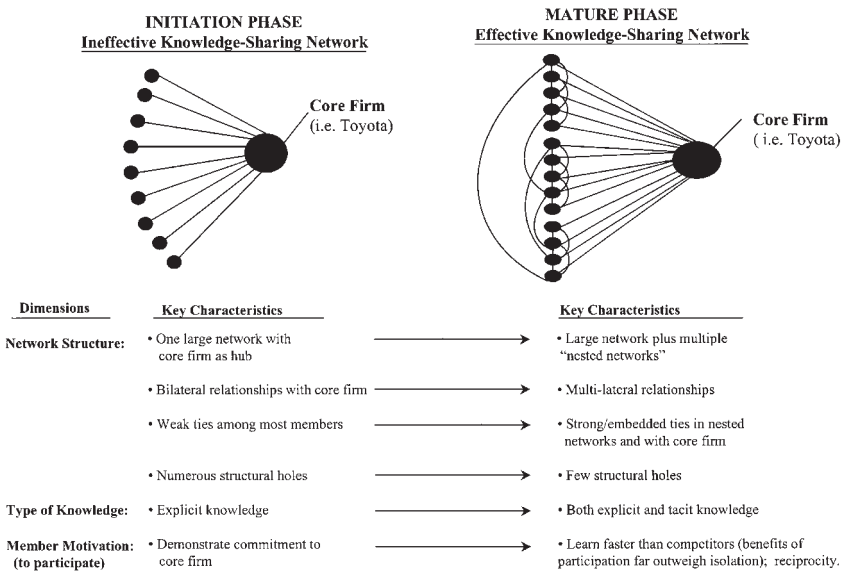

Figure 5. Evolution of a knowledge-sharing network

In the early stages of network formation, there were weak ties among network members and there were numerous structural holes (Burt, 1992). Suppliers were motivated to participate in the supplier association primarily to demonstrate their commitment to Toyota in hopes that Toyota would reward them with more business. The type of knowledge exchanged was primarily explicit knowledge. During this initial phase the network was just beginning to develop an identity, but there was a weak social community and suppliers did not perceive a strong sense of shared purpose with other firms in the network.

However, Toyota gradually built strong bilateral relationships with suppliers through the one-to-one knowledge transfers (consultants) and the supplier association activities. Suppliers began to receive valuable knowledge at minimal cost. Consequently, suppliers increasingly participated in the network not only to demonstrate their commitment to Toyota, but also to receive the knowledge transfers from Toyota. The knowledge exchanged was primarily explicit knowledge in the large network (supplier association) setting, but tacit (and more valuable) knowledge was beginning to be transferred in the bilateral (consulting) setting. During this phase the network began to take on a stronger identity. Suppliers began to feel an obligation to Toyota and began to identify with the network's social community.

The final phase in the evolutionary process was to strengthen multilateral ties among members and develop 'sub-networks' for knowledge sharing within the larger network. This was accomplished through the learning teams which strengthened multilateral ties, thereby facilitating tacit knowledge sharing among suppliers. At this stage of network evolution, the supplier's motivations for participating in network activities are (a) a recognized need for rapid knowledge acquisition, and (b) reciprocity. Suppliers have now experienced the benefits of knowledge sharing. Suppliers also appreciate how important it is, as a Toyota supplier, to rapidly learn and make continuous improvements. Suppliers are kept on their toes by knowing that the rent-creating potential of their past productivity improvements is declining rather fast. Further, they are in a 'learning race' with the other Toyota supplier(s) that produce similar parts in the sense that the fastest-learning suppliers are more likely to get the business for new models. This creates strong incentives for suppliers to learn and improve as quickly as possible. In addition, suppliers now identify with the network and have developed reciprocal obligations for sharing knowledge with other members of the network.

In this mature phase, there are multiple pathways for transferring both explicit and tacit knowledge, with tacit knowledge being exchanged primarily in the sub-networks and the one-to-one

Copyright © 2000 John Wiley & Sons, Ltd.

transfers. Thus, the degree of tacit knowledge being transferred is *substantial* whereas it was almost nonexistent in the initiation phase (see Figure 5). Not surprisingly, suppliers benefit more by participating in network activities because tacit knowledge is typically more valuable than explicit knowledge,. Although the network is becoming an institutionalized knowledge-sharing network, it is still less 'mature' than Toyota's supplier network in Japan. U.S. suppliers are less dependent on Toyota than Japanese suppliers (where affiliated suppliers sell roughly 60 percent of their output to Toyota). As a result, it is easier for Toyota's Japanese suppliers to 'identify' with the Toyota network and participate in knowledge-sharing activities.

Network-vs. organization-level learning

One question worth briefly addressing is whether or not it is possible to distinguish between organization-vs. network-level learning. We believe there is a difference. We view network learning as (a) knowledge development and acquisition that is useful in a *specific network context*, or (b) knowledge (e.g., a best practice) that is developed or resides within the network that is discovered and documented/codified by a network-level knowledge storage mechanism, such as within OMCD or the supplier association. In the first case, new knowledge with regard to how best to coordinate with other firms in the network during the product design phase would be considered network-specific knowledge (and knowledge that is only valuable when multiple firms *share* the same knowledge). In the second case, knowledge acquired, stored, and diffused by the supplier association quality committee (e.g., through its quality training program) would constitute network-level learning. This activity stores knowledge at the network level, and the knowledge is then made widely available for individual member firms to use in changing their individual firm practices. Thus, the changes (learning) that take place at the individual firm level are due to participation in network-level learning activities. We view organizational learning as simply referring to changes/adaptations in an individual firm's processes/routines based on knowledge it generates internally, or on knowledge that it has acquired externally on its own.

CONCLUSION

Our study has a number of implications for both theory and practice. First, our study offers empirical support for the relational view (Dyer and Singh, 1998) which argues that the 'network' is an important unit of analysis for explaining competitive advantage. Our study demonstrates that a network can be more effective than a firm at the generation, transfer, and recombination of knowledge. The primary reason that a network is superior to a firm is that there is greater diversity of knowledge within a network than a firm. Kogut (2000) refers to this as greater 'variety generation' and Gulati and Lawrence (1999) refer to this as 'differentiation.' However, if the network is to be effective at knowledge management, it must create 'coordinating principles' that 'support coordination among specialized firms' (Kogut, 2000). Toyota does this by effectively creating and maintaining an 'identity' for the network as well as an infrastructure that supports knowledge transfers among suppliers. Toyota's ability to effectively create and manage network-level knowledge-sharing processes at least partially explains the relative productivity advantages enjoyed by Toyota and its suppliers (Lieberman *et al.*, 1997; Dyer, 1996). Our study provides evidence that suppliers do learn more quickly after participating in Toyota's network.

Second, we provide insights into the 'coordinating principles' that facilitate cooperation (knowledge transfers) among members in the network. More specifically, Toyota's network has solved three fundamental dilemmas with regard to knowledge sharing in a 'collective' by finding ways to: (1) motivate members to participate and openly share knowledge, (2) prevent members from free riding, and (3) efficiently transfer both explicit and (most importantly) tacit knowledge. Toyota has done this by creating a highly interconnected, strong tie network—a network where members strongly identify with the 'core firm'/network and where there are clear rules for participation in the network's knowledge-sharing activities. Perhaps most importantly, production knowledge is viewed as the property of the network rather than the individual firm.

Third, our research supports Rowley, Behrens, and Krackhardt's (2000) assertion that a highly interconnected, strong tie network is well suited for the diffusion (exploitation) of existing knowl-

Copyright © 2000 John Wiley & Sons, Ltd.

edge rather than exploration for new knowledge (which is the strength of a 'weak tie' network). Toyota's network is largely designed to exploit Toyota's production know-how (e.g., the Toyota Production System) as well as the existing diversity of knowledge that resides within its suppliers. Moreover, a highly interconnected, strong tie network is effective at the diffusion of tacit knowledge because (1) the redundant ties make it easier for network members to locate potentially valuable knowledge, and (2) strong ties produce the trust (social capital) necessary to facilitate the transfer of tacit knowledge.

Fourth, we acknowledge that there are risks to Toyota's approach. First, there is the risk that the diversity of knowledge that resides in the network will diminish over time. As firms in the network become increasingly alike through imitation, the network may be less effective at generating new knowledge. The creation of an identity, or integration, at the network level does not come without a cost (Kogut, 2000; Gulati and Lawrence, 1999). Second, as Afuah's (2000) work suggests, the network may become so inwardly focused that it will be unable to respond to, or adopt, major technological innovations that occur in firms outside of the network. The present highly interconnected network structure seems ideally suited for diffusion of existing knowledge in a mature industry rather than generating new knowledge in a fast-paced, technologically dynamic industry. However, Toyota has adopted some mechanisms to maintain knowledge diversity (e.g., rotating jishuken membership, scanning for 'best practices' outside of the industry through supplier association committee activities). Further, the very process of interactions between firms creates some new knowledge, or at least new applications of existing knowledge.

Fifth, our study provides insights into the evolution of a network, from a collection of dyadic 'weak' ties to a weblike structure with strong, multilateral ties. The evolution of Toyota's network suggests that it takes time to nurture the relationships and processes necessary to facilitate effective learning. The evolution of Toyota's network may explain why Anand and Khanna (2000) found that joint ventures designed for a learning purpose (e.g., R&D alliances) have a 'learning effect' whereas other types of alliances do not. Over time, firms develop the capabilities and processes necessary to facilitate knowledge flows across firm borders (Kale, Singh and Perlmutter, 2000). Also, unlike Hite and Hesterley (1999), who find that entrepreneurial networks evolve from strong ties to weak ties, we find the opposite in Toyota's case. As a large firm with a good reputation and a stock of technical, commercial, and social capital (Ahuja, 2000), Toyota has the luxury of selecting its 'partners' from among the most capable in the world. It then has the challenge of creating strong ties with, and among, those partners.

We see a couple of important directions for future research. First, a comparative study of a sample of different vertical networks with differing degrees of success at knowledge sharing would allow for tests of the ideas offered in this study. Second, future research might examine why Toyota's competitors have not yet been able to imitate the institutionalized knowledge-sharing processes that reside within the Toyota production network. Why aren't other automakers learning from Toyota? This is an important question given that our research demonstrates that network-level knowledge-sharing routines are a critical factor in explaining Toyota's and its suppliers' success. One possibility offered by Garcia-Pont and Nohria (1999) is that the history of cooperation and competition in an industry guides alliance behavior. Perhaps other automakers, particularly U.S. automakers, are constrained by their past history of adversarial relationships with suppliers. Whatever the reason, Toyota does not seem to be particularly concerned. As one Toyota executive observed, 'We are not so concerned that our knowledge will spillover to competitors. Some of it will. But by the time it does, we will be somewhere else. We are a moving target.' This executive is expressing the idea that Toyota's advantage is sustainable because Toyota and its suppliers have a 'dynamic learning capability' and learn at a faster rate than competitors. Our study suggests that the notion of a dynamic learning capability that creates competitive advantage needs to be extended beyond firm boundaries. Indeed, if the network can create a strong identity and effective coordinating rules, then it may be superior to a firm as an organizational form at creating and recombining knowledge owing to the greater diversity of knowledge that resides within a network.

Copyright © 2000 John Wiley & Sons, Ltd.

ACKNOWLEDGEMENTS

The authors would like to thank Masue Suzuki for her able research assistance. We would also like to thank the following individuals at Toyota who were especially helpful throughout the research project: Michio Tanaka (General Manager, International Purchasing); Nobuhiko Suzuki (Manager, International Purchasing); Noriyuki Yokouchi (V.P. Purchasing); Chris Nielsen (Assistant General Manager, Purchasing Planning), Hajime Ohba (General Manager, TSSC); and Lesa Nichols (Assistant Manager, TSSC). We would also like to thank Marvin Lieberman for sharing his data on Japanese and U.S. automotive labor productivity. Finally, the authors would like to thank the Huntsman Center for Global Competition and Innovation at the Wharton School and the International Motor Vehicle Program at MIT for generously supporting this research.

REFERENCES

Afuah, A. (2000). 'How much do your co-opetitors' capabilities matter in the face of technological change?', *Strategic Management Journal*, Special Issue, **21**, pp. 387–404.

Ahuja, G. (2000). 'The duality of collaboration: Inducements and opportunities in the formation of interfirm linkages', *Strategic Management Journal*, Special Issue, **21**, pp. 317–343.

Anand, B. N. and T. Khanna (2000). 'Do firms learn to create value? The case of alliances' *Strategic Management Journal*, Special Issue, **21**, pp. 295–315.

Browning, L., J. Beyer and J. Shetler (1995). 'Building cooperation in a competitive industry: Sematech and the semiconductor industry', *Academy of Management Journal*, **38**(1), pp. 113–151.

Burgelman, R. A. (1994). 'Fading memories: A process theory of strategic business exit in dynamic environments', *Administrative Science Quarterly*, **39**(1), pp. 24–56.

Burt, R. (1992). *Structural Holes: The Social Structure of Competition*. Harvard University Press, Cambridge, MA.

Coase, R. H. (1937). 'The nature of the firm', *Economica*, **4**, pp. 386–405.

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

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

Cusumano, M. A. (1985). *The Japanese Automobile Industry: Technology and Management at Nissan and Toyota*. Harvard University—Council on East Asian Studies, Cambridge, MA.

Dyer, J. H. (1996). 'Specialized supplier networks as a source of competitive advantage: Evidence from the auto industry', *Strategic Management Journal*, **17**(4), pp. 271–292.

Dyer, J. H. and W. G. Ouchi (1993). 'Japanese style business partnerships: Giving companies a competitive edge', *Sloan Management Review*, **35**(1), pp. 51–63.

Dyer, J. H. and H. Singh (1998). 'The relational view: Cooperative strategy and sources of interorganizational competitive advantage', *Academy of Management Review*, **23**(4), pp. 660–679.

Eisenhardt, K. (1989). 'Building theories from case research', *Academy of Management Review*, **14**, pp. 532–550.

Garcia-Pont, C. and N. Nohria (1999). 'Local versus global mimetism: The dynamics of alliance formation in the automobile industry', paper presented at the *SMJ* Special Issue Conference on Strategic Networks.

Gerlach, M. L. (1992). *Alliance Capitalism*. University of California Press, Berkeley, CA.

Glaser, B. and A. Strauss (1967). *The Discovery of Grounded Theory*, Aldine, Chicago, IL.

Gomes-Casseres, B. (1994). 'Group versus group: How alliance networks compete', *Harvard Business Review*, **72**(4), pp. 4–11.

Gouldner, A. W. (1960). 'The norm of reciprocity: A preliminary statement', *American Sociological Review*, **25**(1), pp. 161–178.

Grant, R. (1996). 'Prospering in dynamically-competitive environments: Organizational capability as knowledge integration,' *Organization Science*, **7**(4), pp. 375–387.

Gray, B. (1989). *Collaborating: Finding Common Ground for Multiparty Problems*. Jossey-Bass, San Francisco, CA.

Gulati, R. and P. Lawrence (1999). 'Organizing vertical networks: A design perspective,' paper presented at the *SMJ* Special Issue Conference on Strategic Networks.

Hite, J. and W. Hesterly (1999). 'The influence of the firm life cycle on the evolution of entrepreneurial firm networks', paper presented at the *SMJ* Special Issue Conference on Strategic Networks.

Kale, P., H. Singh and H. Perlmutter (2000). 'Learning and protection of proprietary assets in strategic alliances: Building relational capital' *Strategic Management Journal* Special Issue **21**, pp. 217–237.

Kogut, B. (2000). 'The network as knowledge: Generative rules and the emergence of structure', Strategic Management Journal, **21**, Special Issue, pp. 405–425.

Kogut, B. and U. Zander (1992). 'Knowledge of the firm, combinative capabilities, and the replication of technology', *Organization Science*, **3**(3), pp. 383–397.

Kogut, B. and U. Zander (1996). 'What firms do? Coordination, identity, and learning,' *Organization Science*, **7**(5), pp. 502–518.

Copyright © 2000 John Wiley & Sons, Ltd.

Levinson, N. S. and M. Asahi (1996). 'Cross-national alliances and interorganizational learning,' *Organizational Dynamics*, **24**, pp. 51–63.

Levitt, B. and J. G. March (1988). 'Organizational learning,' *Annual Review of Sociology*, **14**, pp. 319–340.

Lieberman, M. (1994). 'The diffusion of "lean manufacturing" in the Japanese and U.S. automotive industry', presented at 'New Imperatives for Managing in Revolutionary Change' Conference, Shizuoka, Japan, 28–30 August.

Lieberman, M. and S. Asaba (1997). 'Inventory reduction and productivity growth: A comparison of Japanese and U. S. automotive sectors', *Managerial and Decision Sciences*, **18**, pp. 73–85.

Lieberman, M., M. Sako, K. Wada and L. Demeester (1997). 'The productivity-enhancing impact of suppliers associations in the Japanese auto industry', IMVP Sponsors Forum, Kyung Ju, Korea, 25 September.

Lincoln, J. R., M. Gerlach and P. Takahashi (1992). '*Keiretsu* networks in the Japanese economy: A dyad analysis of intercorporate ties', *American Sociological Review*, **57**, pp. 361–585.

Lorenzoni, G. and A. Lipparini (1999). 'The leveraging of interfirm relationships as a distinctive organizational capability: A longitudinal study', *Strategic Management Journal*, **20**(4), pp. 317–338.

MacDuffie, J. P. and S. Helper (1997). 'Creating lean suppliers: Diffusing lean production throughout the supply chain', *California Management Review*, **39** (4), pp. 118–134.

March, J. G. and H. A. Simon (1958). *Organizations*. Wiley, New York.

Marsden, P. V. (1990). 'Network data and measurement', *Annual Review of Sociology*, **16**, pp. 435–463.

Marwell, G. and P. Oliver (1993). *The Critical Mass of Collective Action: A Micro-social Theory*. Cambridge University Press, Cambridge, U.K.

Nelson, R. and S. Winter (1982). *An Evolutionary Theory of Economic Change*. Harvard University Press, Cambridge, MA.

Nishiguchi, T. (1994). *Strategic Industrial Sourcing*. Oxford University Press, New York.

Nonaka, I. (1994). 'A dynamic theory of organizational knowledge', *Organization Science*, **5**, pp. 14–37.

Powell, W. W. (1996). 'Inter-organizational collaboration in the biotechnology industry', *Journal of Institutional and Theoretical Economics*, **152**, pp. 197–225.

Powell, W. W., K. W. Koput and L. Smith-Doerr (1996). 'Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology', *Administerative Science Quarterly*, **41**, pp. 116–145.

Rowley, T. D. Behrens and D. Krackhardt (2000). 'Redundant governance structures: An analysis of structural and relational embeddedness in the steel and semiconductor industries', *Strategic Management Journal*, Special Issue, **21**, pp. 369–386.

Ryle, G. (1984). *The Concept of Mind*. University of Chicago Press, Chicago, pp. 29–34.

Sako, M. (1997). 'Knowledge diffusion in the U.K. automotive industry', IMVP Sponsors' Forum, Kyung Ju, Korea, 25 September.

Sandler, T. (1992). *Collective Action: Theory and Applications*. University of Michigan Press, Ann Arbor, MI.

Spender, J.-C. (1996). 'Making knowledge the basis of a dynamic theory of the firm', *Strategic Management Journal*, Winter Special Issue, **17**, pp. 45–62.

Strauss, A. and J. Corbin (1990). *Basics of Qualitative Research*. Sage, Newbury Park.

Szulanski, G. (1996). 'Exploring internal stickiness: Impediments to the transfer of best practice within the firm', *Strategic Management Journal*, Winter Special Issue, **17**, pp. 27–43.

Teece, D. J., G. Pisano and A. Shuen (1997) 'Dynamic capabilities and strategic management', *Strategic Management Journal*, **18**(7), pp. 509–533.

von Hippel, E. (1988). *The Sources of Innovation*. Oxford University Press, New York.

Webb, E. J. (1981). *Nonreactive Measures in the Social Sciences*. Houghton Mifflin, Boston, MA.

Williamson, O. E. (1985). *The Economic Institutions of Capitalism*. Free Press, New York.

Wood, D. J. and B. Gray (1991). 'Toward a comprehensive theory of collaboration', *Journal of Applied Behavioral Science*, **27**(2), pp. 139–162.

Copyright © 2000 John Wiley & Sons, Ltd.