

RELATION-SPECIFIC CAPABILITIES AND BARRIERS TO KNOWLEDGE TRANSFERS: CREATING ADVANTAGE THROUGH NETWORK RELATIONSHIPS

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This study examines the role of network knowledge resources in influencing firm performance. More specifically: Can a firm that uses the identical supplier network as competitors and purchases similar inputs from the same plants achieve a competitive advantage through that network? In a sample of U.S. automotive suppliers selling to both Toyota and U.S. automakers, we found that greater knowledge sharing on the part of Toyota resulted in a faster rate of learning within the suppliers' manufacturing operations devoted to Toyota. Indeed, from 1990 to 1996 suppliers reduced defects by 50 percent for Toyota vs. only 26 percent for their largest U.S. customer. The quality differences were found to persist within suppliers because the inter-organizational routines and policies at GM, Ford, and Chrysler acted as barriers to knowledge transfers within suppliers' plants. These findings empirically demonstrate that network resources have a significant influence on firm performance. We also show that some firm resources and capabilities are relation-specific and are not easily transferable (redeployable) to other buyers or networks. This result implies that a firm may be on its production possibility frontier for each customer but the productivity frontier will be different for each customer owing to constraints associated with the customer's network. Copyright © 2006 John Wiley & Sons, Ltd.

INTRODUCTION

We are not so concerned that our knowledge will spill over to competitors. Some of it will. But by the time it does, we will be somewhere else. We are a moving target.

Michio Tanaka, International Purchasing General Manager, Toyota

A fundamental question in strategy research is why firms differ in their performance. In answering this question, researchers have typically chosen to view firms as autonomous entities, striving for

advantage through favorable industry conditions (Porter, 1980) or internal resources and capabilities (Wernerfelt, 1984; Barney, 1991). As noted by Gulati, Nohria, and Zaheer (2000: 204) 'strategy research has generally not looked to place the source of differences in interfirm profitability as arising from the varying participation of firms in strategic networks.' More recently, scholars have argued that a firm's performance may be strongly influenced by its interfirm ties or its 'strategic networks' (Dyer and Singh, 1998; Gulati *et al.*, 2000).

Gulati (1999: 399) argued that a firm's network may offer 'network resources that are the source of valuable information for firms.' Similarly, Dyer and Singh (1998: 662) identified interfirm knowledge-sharing routines as one of four possible sources of 'relational rents' which are 'supernormal

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profit[s] generated in an exchange relationship that cannot be generated by either firm in isolation.' Dyer and Singh (1998: 665) define an interfirm knowledge-sharing routine as 'a regular pattern of interfirm interactions that permits the transfer, recombination, or creation of specialized knowledge.' A firm that is able to participate in a network with established routines for efficient knowledge transfer among members would be expected to have advantages over firms without access to those network knowledge resources. Following Gulati (1999), we define network resources as *valuable knowledge acquired through the network*.

Unfortunately, theoretical arguments that competitive advantage can be achieved through superior knowledge sharing within networks have largely gone untested. In this paper we explicitly consider the effects of network resources (knowledge) on firm performance and, in a conservative test of the theory, demonstrate that network resources result in differential firm performance even in supplier networks where rivals are buying from the same suppliers. The current theoretical view on this topic is that two firms with equivalent networks should enjoy similar benefits from its strategic networks. As Gulati *et al.* (2000: 212) observe, 'Firms that are in the same clique or are structurally equivalent may behave similarly and enjoy similar returns.' Our research demonstrates that under certain conditions a firm can achieve competitive advantages through a structurally equivalent strategic network.

Recently Japanese automakers have transplanted most of the auto production for their U.S. sales to the United States. To meet local content requirements they have also transferred a large percentage of their parts purchases to U.S. suppliers. For example, in 2000 Toyota purchased more than 70 percent of the total value of its parts (in the United States) from U.S. suppliers. Consequently, Toyota is increasingly using the identical supplier network as its U.S. competitors. This raises the question: *Can a firm that uses the identical supplier network as its competitors, to purchase similar inputs, achieve a competitive advantage through that network?* The network literature suggests that this is unlikely (Gulati *et al.*, 2000). Moreover, traditional economic theory suggests an advantage is possible only if the buying firm can extract lower unit prices from suppliers due to greater relative bargaining power than its competitors (Porter, 1980). But in the United States Toyota has less relative

bargaining power than its U.S. competitors owing to smaller volumes, suggesting that U.S. automakers should have any differential advantage.

One possible way for Toyota to *create* competitive advantages through an identical supplier network would be for Toyota to share its knowledge with those suppliers and improve joint performance (Dyer and Singh, 1998). For example, Toyota could attempt to leverage its knowledge by transferring knowledge and technology to enhance the productivity of its supplier network. However, there is a problem in *sustaining* network advantages when competitors have equal access to those network resources. If a buyer transfers valuable knowledge to a particular supplier, what is to prevent the supplier from utilizing that knowledge in supplying products to the buyer's competitors? Neoclassical, Marshallian economic theory indicates that 'any feasible pattern of activity can be faultlessly replicated' (Nelson and Winter, 1982: 117) and that knowledge replication is essentially 'costless and simultaneous' (Shannon and Weaver, 1949; see Szulanski, 2000: 10).

In contrast, this study demonstrates that a firm can in fact create and sustain competitive advantages through network resources and calls into question the adequacy of current theoretical perspectives on network resources and barriers to knowledge replication. We examine these questions in the context of the automotive industry, where Toyota is known for attempting to leverage its knowledge assets by sharing production knowledge with its supplier network. Indeed, in 2003 Toyota's net profit was larger than the *combined* profits of GM, Ford, and DaimlerChrysler. Moreover, according to JD Power's Initial Quality Studies, Toyota's vehicles had roughly 40 percent fewer defects than those same competitors. While there are many possible pathways to competitive advantage, Toyota's path has clearly allowed its profits to dwarf those of its major competitors in recent years. We seek to explain one element of Toyota's competitive advantage: its relational advantage secured through knowledge sharing within its supplier network. In this light, it is important that the reader understand the dual nature of this research investigation. The first objective is to empirically examine the relationship between customer-to-supplier knowledge-sharing activities and the rate of improvement in supplier network performance. We test the hypothesis that a buyer that provides greater knowledge transfers to its

supplier network will develop the suppliers' production capabilities such that the suppliers' operations for that particular buyer will be more productive. This is the *creation* of relational competitive advantage. The empirical findings from this part of the investigation confirm that Toyota's supplier network does produce components of higher quality, and at lower cost, for Toyota than for their largest U.S. customer. The second objective is to explore why the supplier performs better as a member of one network (i.e., Toyota's) than another network (i.e., GM, Ford, or Chrysler). In short, we examine why the network resources created by Toyota do not flow to GM even though GM has ties with that same network. Thus, we also address the *sustainability* of competitive advantage achieved through network resources. This is an important question because suppliers have a fully functioning 'template' that should make possible a 'relatively precise transfer' (replication) of the production routines to support other customers (Nelson and Winter, 1982: 120).

THEORY AND HYPOTHESES

Proponents of the resource-based view have emphasized that competitive advantage results from those resources and capabilities that are owned and controlled by a single firm (Wernerfelt, 1984; Barney, 1986). Consequently, the search for competitive advantage has focused on resources and capabilities that are housed *within the firm*. Competing firms purchase factors of production (inputs) which cannot be sources of advantage because these factors are either readily available to all competing firms or the cost of acquiring these factors is approximately equal to the economic value they create (Barney, 1986; Teece, Pisano, and Shuen, 1997). This would be particularly true when manufacturers purchase the same inputs from the same suppliers. Under these conditions it would be extremely difficult for a buyer to create competitive advantages through a shared supplier network.

In this paper we consider the case where a buyer wants to create network resources by leveraging its knowledge assets within its supplier network. At first glance, a strategy of leveraging knowledge assets with suppliers appears attractive because once the buyer has accumulated knowledge assets they can be reused at minimal additional cost. However, the cost of transferring knowledge to

be used at multiple locations (perhaps by multiple firms) will depend on the attributes of the knowledge. Explicit (codifiable) knowledge is relatively easy to transfer with little cost, while tacit knowledge is more difficult and costly to transfer (Kogut and Zander, 1992; Szulanski, 1996; Hatch and Mowery, 1998). A buyer who desires to create competitive advantage through knowledge transfers to its supplier network risks having the value of its knowledge transfers to a supplier network dissipated through knowledge spillovers to competitors who use the same suppliers. Attempts to create network resources by leveraging knowledge assets are obviously of greater strategic interest when the derived advantage is sustainable. Thus, to create sustained advantages for the buyer, the supplier's newly acquired knowledge assets (production capabilities) must be at least somewhat *specific to the relationship (network)*. Something must prevent competitors from tapping into those network resources through ties with members of that same network.

Barriers to the flow of knowledge across networks

We adopt the language of evolutionary economics in arguing that knowledge assets are embedded in firm routines (Nelson and Winter, 1982). In turn, firm routines are the basis of firm capabilities. A firm (i.e., a supplier) will only have acquired valuable knowledge assets through its network ties after it successfully implements a new set of routines for conducting productive activity. According to both the evolutionary economics and dynamic capabilities perspectives, transfer of knowledge within firms (and certainly across networks) is likely to be difficult. As Nelson and Winter (1982: 118) state: 'We think of replication as being a costly, time-consuming process of copying an existing pattern of productive activity ... Further, we regard the feasibility of close (let alone perfect) replication as being quite problematic.' Additional research indicates that there are substantial barriers to knowledge transfers that make it difficult to transfer knowledge within the firm (Leonard, 1995; Szulanski, 1996; Knott, 2003). Specifically, Szulanski (1996) suggests that the major barriers to intra-firm transfers of knowledge (best practice) include: (1) lack of absorptive capacity on the part of the recipient of knowledge; (2) lack of credibility on the part of the

source of knowledge; (3) lack of motivation on the part of the 'source' or 'recipient' of knowledge; (4) arduous relationship between the source and recipient; and (5) causal ambiguity (due to the complexity of knowledge). Szulanski (1996: 28) found that 'Contrary to conventional wisdom that places primary blame on motivational factors, the major barriers to internal knowledge transfer are shown to be knowledge-related factors, such as the recipient's lack of absorptive capacity, causal ambiguity, and an arduous relationship between the source and recipient.' Both Szulanski (1996) and Nelson and Winter (1982) additionally point to 'context' (the environment) as another potential barrier to replication. However, Szulanski (1996) finds no empirical support in his study for context as a barrier to transfer of best practices.

Although little empirical research has been done on how context could act as a barrier to knowledge transfers (either within firms or across networks), one could imagine that a highly co-specialized production system could be based on knowledge and capabilities that are specific to a relationship (Teece, 1986). For example, previous research suggests that the ability of a firm to effectively implement the 'Toyota Production System' (e.g., Kanban, Heijunka, JIT) depends on the stability of its customer orders and the inter-organizational processes which pull inventory through the value chain (Womack, Jones, and Roos, 1990; Helper and Sako, 1995). If customer orders fluctuate wildly or if key inter-organizational processes are not in place, a supplier may be unable to minimize inventory safety stocks if it is going to provide just-in-time deliveries. The point is that a firm's internal routines or production capability may, to some extent, be contingent on the *inter-organizational* routines which constitute the network 'context' linking the firm's production system to the systems of its customers and suppliers. According to this logic, it may be possible for a buyer to exploit its knowledge assets by sharing them with suppliers in return for lower cost and/or higher quality inputs. This will create advantages for the buyer's network as long as the knowledge transferred has a relationship-specific component to it.

The automotive industry offers a useful research setting to test these ideas for two reasons: (1) the automobile is a complex product that requires large and diverse supplier networks to participate in the production of components and subsystems;

and (2) some firms have attempted to achieve advantages in the marketplace by creating network resources via leveraging production knowledge with suppliers. Prior research shows that Toyota and Honda have purposefully established higher-order inter-organizational routines designed to facilitate the transfer of lower-order routines (the set of specific production routines that comprise the Toyota Production System; MacDuffie and Helper, 1997; Dyer and Nobeoka, 2000). To be effective, these complex production routines need to be adopted simultaneously as a bundle of routines (MacDuffie, 1995; Milgrom and Roberts, 1992). The difficulties of adopting a complete bundle of routines represent a key piece in the puzzle of why network resources are not easily imitated.

To solve the complicated puzzle of creating network resources, Toyota has established a supplier association and consulting teams with the explicit objective of creating network resources. Supplier associations facilitate knowledge sharing within the network by organizing monthly meetings with automaker and supplier personnel to share knowledge on production techniques (Sako, 1996). Toyota's supplier association in Japan (*kyohokai*) has created committees focused on cost reduction, quality improvement, and safety. These committees facilitate learning on a particular topic by developing training programs and organizing visits to 'best practice' plants (Dyer and Nobeoka, 2000). The goal is to leverage the knowledge assets that reside within Toyota and its supplier network by assisting suppliers to replicate the 'best practice' production routines within their plants. In a move to replicate some of these advantages, Toyota established a supplier association in the United States in 1989 to facilitate knowledge sharing with its U.S. suppliers.

In addition to supplier associations, case studies by MacDuffie and Helper (1997) and Dyer and Nobeoka (2000) provide anecdotal evidence that consulting teams at Toyota and Honda have been effective at transferring knowledge to suppliers and improving their productivity and quality. Toyota's Operations Management Consulting Group (OMCD) in Japan has provided on-site knowledge transfers at suppliers' plants since 1977, while the U.S. consulting group (the Toyota Supplier Support Center) has provided assistance to U.S. suppliers since 1992. These consultants (roughly 60 in Japan and 20 in the United States) are experienced

Toyota personnel with in-depth knowledge of the principles and practices of the Toyota Production System. Dyer and Nobeoka (2000) report that U.S. automotive suppliers have made significant reductions in inventories as well as increases in output per labor hour after 2 years of interaction with the Toyota consultants.

Collectively, these prior studies provide *anecdotal* evidence that Toyota engages in greater knowledge sharing with suppliers than does its U.S. competitors. Some scholars also speculate that these knowledge-sharing activities produce 'reciprocal learning,' which translates into the accumulation of greater knowledge assets at both Toyota and its suppliers (see Fruin and Nishiguchi, 1993). However, *these assertions have not been empirically tested*. Furthermore, prior studies that speculate on the positive relationship between network-level knowledge transfers and performance have occurred in an institutional environment where many suppliers are partly owned by a particular automaker customer and sell the majority of their output to a single customer (Cusumano, 1985; Gerlach, 1992). Consequently, the automaker is better able to appropriate the benefits from knowledge-sharing activities that improve the productivity and quality of its suppliers. Prior research sheds little insight into whether a buyer is able to generate and sustain competitive advantage through knowledge transfers to a supplier network that is shared with competitors. Thus, the case of Toyota working with U.S. suppliers offers a natural experiment to test whether firms can achieve competitive advantage by leveraging knowledge assets (network resources) with suppliers. In summary, we test the following hypotheses:

Hypothesis 1: The quality of a supplier's product for a particular customer will be higher, relative to the quality for other customers, when that supplier has received more quality assistance (knowledge transfers) from that particular customer.

Hypothesis 2: The productivity of the supplier's operations for a particular customer will be higher, relative to the productivity of operations for other customers, when that supplier receives more productivity assistance (knowledge transfers) from that particular customer.

Exploratory study: sustainability of relational advantages

Although these hypotheses assert a positive relationship between knowledge transfers and supplier performance, it is possible that suppliers quickly transfer the newly acquired production knowledge to service all customers. If this is the case, each supplier's performance should be identical for each customer. For the hypotheses above to confer sustainable competitive advantage, it must be true that either: (1) the supplier *cannot* transfer the knowledge acquired from one customer to its operations dedicated to other customers (e.g., due to barriers); or (2) there is a substantial time lag in transferring the knowledge. However, since the supplier has a fully functioning template to replicate elsewhere in the same plant that is producing for Toyota's rivals, replication within the same plant would certainly appear feasible, if not expected, especially since the barriers to knowledge transfer identified by Szulanski (absorptive capacity and arduous relationship) do not appear to apply. If barriers to replication do not exist, we would expect to see performance of all manufacturing cells within a supplier plant converge as all cells adopt the best practices learned from various customers. In contrast, if barriers to replication do exist, the performance within different manufacturing cells may persist and even grow over time.

Our unit of analysis is the manufacturing cells within a supplier plant where we compare the quality and productivity of the plant's Toyota-specific operations with those of its operations dedicated to its U.S. customers. It is hard to argue that the plant manager and his assistants do not have the absorptive capacity or credibility necessary to transfer the valuable knowledge from one manufacturing cell to another since they have already implemented the new processes for Toyota within the plant. Furthermore, since the plant manager and his assistants are both the source and the recipient of knowledge it seems unlikely that an arduous relationship could prevent an intra-firm transfer of knowledge.¹ Moreover, if personnel from a different manufacturing cell were unwilling to implement new processes that were proven

¹ Of course, the manufacturing cell for the U.S. OEM may have a different supervisor and different workers so we cannot discount this reason completely.

in a different part of the plant, the plant manager can replace the employees. Of course, 'causal ambiguity' or 'context' could also act as barriers to replication within the supplier's plant. To fully explain the inability of suppliers to transfer knowledge within their plants, we conducted an exploratory study to examine why differences in supplier quality/productivity might persist for different customers.

RESEARCH METHODS

Sample

The sample was drawn from a population of all 97 U.S.-based suppliers who were listed as members of Toyota's U.S. supplier association called Bluegrass Automotive Manufacturers Association (BAMA). A survey was pre-tested during interviews with plant managers and their top assistants at 10 suppliers and follow-up interviews were done at 13 suppliers (the original 10 plus three additional suppliers) to explore the results. The survey was then sent to the plant managers (head of plant operations) at the 97 suppliers in the supplier association in May of 1997. Our questions were asked with regard to the plant's highest dollar volume component for Toyota and the same component for their largest U.S. OEM. On average, responding suppliers sold 50 percent *more* of the same component to the U.S. OEM than to Toyota during the 1990–96 time frame. The respondents were asked to compare the knowledge-sharing activities in which personnel from their plant were engaged with Toyota compared to their largest U.S. customer. Then, the plant managers provided data on (1) the quality of their products produced for each customer, and (2) the inventory levels of their manufacturing operations for each customer.² These comparisons were made with regard to the same component so the sample is essentially a matched sample. Responses were received from 54 suppliers. After eliminating five suppliers due to insufficient data and seven suppliers because they did not sell to a U.S. OEM,

the final sample was 42 suppliers. The requirement that suppliers be both members of BAMA and sell to a U.S. OEM ensures that supplier networks are the same for Toyota and the U.S. OEMs. In other words, any advantage accruing to Toyota does not come from working with superior suppliers.

Key informants are acceptable in this study because key informants (especially CEOs or the top organization officer) have been identified as being preferred over multiple informants when (a) the selected person is uniquely qualified to respond to the issues under investigation (Kumar, Stern, and Anderson, 1993; Hambrick, 1981), and (b) the questions asked are on 'global' strategic issues or issues related to 'external' relationships (higher 'cosmopolitan' content). Under such conditions, some studies have found that single informants were closer to 'correct' than subordinates in their assessment of external (higher cosmopolitan content) strategic issues (Sharfman, 1998; Hambrick, 1981). In this study, we examine knowledge sharing between a supplier plant and its multiple customers. Thus, the plant manager is uniquely positioned to be aware of all of the visits and knowledge-sharing initiatives between his various customers and his plant personnel and therefore is in the best position to report on those activities. Moreover, the average tenure of a plant manager was 12 years (range 2–33 years; S.D. 7.8) indicating that plant managers were well positioned to report on knowledge-sharing activities over time.

To assess the likelihood of non-response bias influencing the results, we compared the results for early responders with those of late responders (Armstrong and Overton, 1977). No significant differences were found between early and late respondents on any of the variables used in the study. Moreover, we also compared the sales volume to Toyota for the responders vs. non-responders and found no significant differences. Since our response rate was over 50 percent, we feel it is unlikely that non-response bias would unduly influence our results.

Operational measures

Suppliers were asked to report on their experience with each customer from 1990 to 1996. We chose 1990 as a base year for two reasons. First, Toyota opened its first wholly owned U.S. plant

² Productivity and quality differences could exist for different customers because, in most cases, the suppliers used different manufacturing cells for each customer due to (a) differences in the timing and length of the contract to provide the component, and (b) minor differences in designs for each customer.

in Georgetown, Kentucky, in 1988, so most of the suppliers had only been working with Toyota since that year or later. Second, Toyota started its supplier association in 1989, which initiated its knowledge-sharing activities with U.S. suppliers. Measures were then developed to operationalize the degree to which each customer had exchanged knowledge with the supplier to help the supplier improve (1) quality and (2) inventory costs.

Time spent on knowledge transfers

Respondents reported on the number of days per year that personnel from the automaker and supplier had met on a face-to-face basis to exchange technical information *at the supplier's plant*. This was measured by having the plant manager identify the average number of days per year that personnel from this customer visited to exchange technical information and provide assistance (variable: *FaceDays*).

We acknowledge that time spent on knowledge-sharing activities does not necessarily correlate with knowledge acquired (perhaps due to ineffective knowledge transfer processes). Consequently, we had plant managers provide an assessment of the extent to which they had actually acquired valuable knowledge from each customer to help them improve quality or costs.

Quality assistance. Supplier respondents were asked to report on the extent to which they had received quality assistance from each customer (variable: *QualityAssistance*). This was done by having suppliers respond to the following survey item: *To what extent has this customer provided assistance to help you reduce defects and increase the overall reliability and quality of the products you sell?* (Likert scale: 1 = Not at all; 4 = To some extent; 7 = Great extent).

Inventory/cost assistance. The extent to which each customer provided inventory assistance was operationalized by having suppliers respond to the following survey item: *To what extent has this customer provided assistance to help you develop a more efficient inventory management system (i.e., a just-in-time system) designed to lower inventory costs and/or make delivery more efficient?* (Likert 1–7 scale: 1 = Not at all; 4 = To some extent; 7 = Very great extent; variable: *Inventory/Assistance*).

Performance variables

Performance data were gathered with regard to the relative product quality and relative inventory levels for each customer. Performance data were provided by the respondent for the years 1990, 1992, 1994, and 1996. Longitudinal data were obtained to track performance changes over time to develop a measure of the rate of improvement.

Product quality

We used the plant's number of defective parts per million produced for each customer as a measure of quality (variable: *Defects*). This measure is based on a statistical sampling of parts at the supplier's plant. Defects in parts per million must be provided to the automaker as evidence of the supplier's quality.³ The performance improvement in defects is reflected in the change in defects from 1990 to 1996 (*DefectsChange*).

Inventory costs

Previous research has found a strong correlation between inventory reductions and productivity growth (Lieberman and Demeester, 1999). As suppliers learn better methods for minimizing inventories, there is the potential to minimize investments in inventories as well as scrap and rework. We used inventories (raw materials, WIP, and finished goods) directly attributable to each customer as a percent of sales to that customer as a measure for inventory costs (variable: *Inventory/Sales*). Rate of improvement would be reflected in the *Inventory/Sales Change* from 1990 to 1996.

To ensure that the performance data provided by the plant managers were accurate, we followed up with the plant finance officer/accountant or assistant plant manager at eight plants to corroborate the 'objective' performance numbers supplied

³ According to Chris Nielsen, Toyota's U.S. Purchasing General Manager, when suppliers reduce their defects in parts per million for Toyota, it has both an effect on cost (by reducing the number of parts that need to be scrapped) and on quality (when suppliers install processes that reduce defects in parts per million, these processes also reduce the variation in their production processes, thereby improving the conformance quality of the non-rejected parts that go to Toyota; States Nielsen, 'Toyota understands that as suppliers reduce their defects in parts per million, they are improving their processes for making high quality parts. Naturally, this improves the reliability of our cars and our ability to charge a premium in the marketplace' (author interview, November 4, 2002).

by the plant manager. In every case but one (where the differences were within 10%), the only differences between what the plant manager reported (on defects and inventory to sales) and what the finance officer reported could be accounted for by rounding error.

Data analysis

We use regression analysis to test the hypothesized influence of time spent on knowledge-sharing activities (*FaceDays*) and perceived knowledge acquired (*QualityAssistance*, *Inventory Assistance*) on performance (*DefectsChange*, *Inventory/Sales Change*) (see Figure 1). The inherent firm-level differences in defects and inventory levels pose a challenge to our attempts to directly test the relationship between the knowledge-sharing variables (e.g., face-to-face contact days at the plant) and the performance variables. These firm-level performance differences are driven by the fundamental differences in the products in our sample. For example, metal body stampings incur higher inventory costs as a percent of sales than sunvisors. Ideally, we would control for these component-specific (firm-specific) effects using a fixed-effects model. Unfortunately, this is not possible because we have only one observation of the *rate* of performance improvement per firm. To use a full fixed-effects model would leave us with negative degrees of freedom.

In place of a fixed-effects model, we examined the relationship between *relative knowledge sharing* and *relative performance*, which allow us to mitigate the problems associated with component-specific differences. This is done by testing for a relationship between the *difference* in the supp-

lier's knowledge-sharing activities for each customer with the *difference* in the supplier's quality and inventory/sales performance improvement for each customer. To illustrate, for each knowledge-sharing measure, the supplier's response for the U.S. OEM was subtracted from the supplier's response for Toyota. This produced a measure of the extent to which Toyota provided more, or less, knowledge exchange on that particular measure. For example, if a supplier received 13 days of visits from Toyota, but only 6 days of visits from the U.S. OEM, the difference in OEM face days (*dFaceDays*) would be +7. We then regress the dependent variable (difference in the rate of performance improvement) on this number. For example, if the same supplier reduced its defects by 90 percent for Toyota (−0.90), but only 50 percent (−0.50) for its U.S. OEM, then the difference in rate of improvement in performance would be −0.40. This gives us the following specification for tests of Hypotheses 1 and 2:

$$\begin{aligned} dDefectsChange &= DefectsChange_{Toyota} \\ &\quad - DefectsChange_{US\ OEMs} \\ &= \beta_0 + \beta_1 dOEMFaceDays \\ &\quad + \beta_2 dQualityAssistance \\ dInventory/SalesChange &= Inventory/SalesChange_{Toyota} \\ &\quad - Inventory/SalesChange_{US\ OEMs} \\ &= \beta_0 + \beta_1 dOEMFaceDays \\ &\quad + \beta_2 dInventoryAssistance \end{aligned}$$

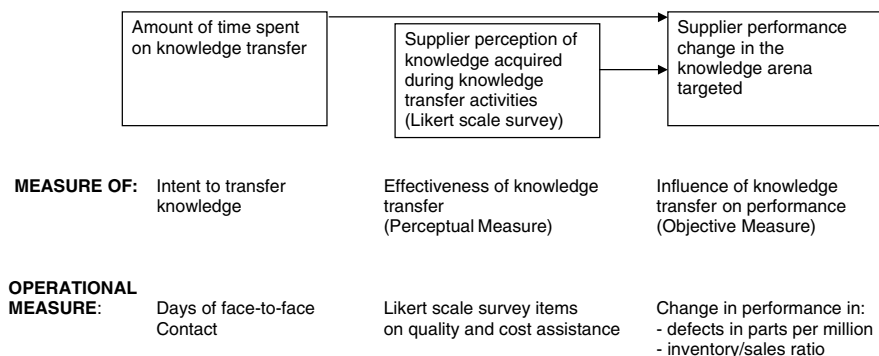


Figure 1. Examining the relationship between customer-to-supplier knowledge transfers and supplier performance improvement

where $dDefectsChange$ is the difference in the rate of improvement of defects, $dInventory/SalesChange$ is the difference in the rate of improvement in inventory/sales, and $dOEMFaceDays$, $dQualityAssistance$, and $dInventoryAssistance$ are differences in their respective variables.

Despite our efforts to capture and analyze the relationship between knowledge-sharing activities and performance, when interpreting the results of the regression analysis the reader should be aware of the difficulties in finding such a relationship. In the regression models employed here, we were able to control for firm-specific differences only through the use of relative knowledge sharing and relative performance improvement variables. Some suppliers may simply be better at making improvements in performance regardless of whether they receive outside assistance. Furthermore, some suppliers may receive greater assistance precisely *because* they are performing poorly and are having a difficult time making improvements.⁴ If so, this will work against the statistical tests of our hypotheses that greater assistance (knowledge exchanges) will lead to improved performance. Thus, our statistical results are conservative tests of the hypotheses.

⁴ Toyota indicated that suppliers who are ineffective at improving performance are likely to receive *more* assistance in terms of days of visits from Toyota. After Toyota provides some minimum threshold level of training and instruction for suppliers, some suppliers are better than others at assimilating the knowledge and making changes that result in performance improvements. As a result, Toyota may provide less ongoing assistance to the 'fast-learning' suppliers than they do to the 'slow-learning' suppliers. This does not negate the positive relationship between knowledge-sharing activities and performance, but it does mean that finding a relationship between knowledge-sharing activities and performance is particularly challenging owing to supplier-specific differences.

RESULTS

The descriptive statistics and univariate tests for significant differences in the matched sample means are shown in Table 1. The data indicate that Toyota spends significantly more time on knowledge-sharing activities than do GM, Ford, or Chrysler. Toyota sends personnel to suppliers for 12 days each year vs. 6 days for U.S. OEM customers. Respondents also report receiving significantly more quality and inventory assistance from Toyota. The data also suggest that the suppliers' defects and inventories are lower, on average, for Toyota than for their U.S. customer. By 1996, defects (ppm) averaged 219 for Toyota in 1996 vs. 428 for the U.S. customer. These differences were statistically significant. Similarly, inventories as a percentage of sales were almost 25 percent lower for Toyota than for the U.S. OEM and these differences were also statistically significant. Moreover, the supplier lowered their defects and inventories at a significantly faster rate in their Toyota operations.

The performance data are shown over time (1990–96) in Figure 2. The longitudinal data indicate that suppliers performed roughly the same for Toyota on both measures in 1990 but better on both measures by 1996. One possible reason for the suppliers' relatively poor showing for Toyota in 1990 is that most suppliers were in a 'start-up' situation with Toyota and were running unit volumes that were 20 percent of the volumes for their largest U.S. OEM. By 1996, the suppliers were more productive for Toyota despite 50 percent lower unit volumes. The data in Table 1 and Figure 2 provide preliminary support for Hypotheses 1 and 2.

Table 1. Descriptive statistics: means and (standard deviations)

	U.S. OEM $N = 42$	Toyota $N = 42$	Different means t -value
<i>Knowledge-sharing variables</i>			
Face days	6.2 days (10.2)	11.7 days (19.1)	2.6***
Quality assistance (1–7)	2.7 (1.5)	4.4 (1.8)	5.5***
Inventory assistance (1–7)	1.8 (1.0)	4.5 (1.8)	8.8***
<i>Performance variables</i>			
Defects in PPM (1996)	428 (572)	219 (253)	2.4***
Defects change (1990–96)	–26% (47%)	–50% (44%)	4.3***
Inventory/sales (1996)	6.0% (3.6%)	5.0% (2.5%)	3.9***
Inventory/sales change (90–96)	–9.0% (8.5%)	–23% (12%)	6.7***

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

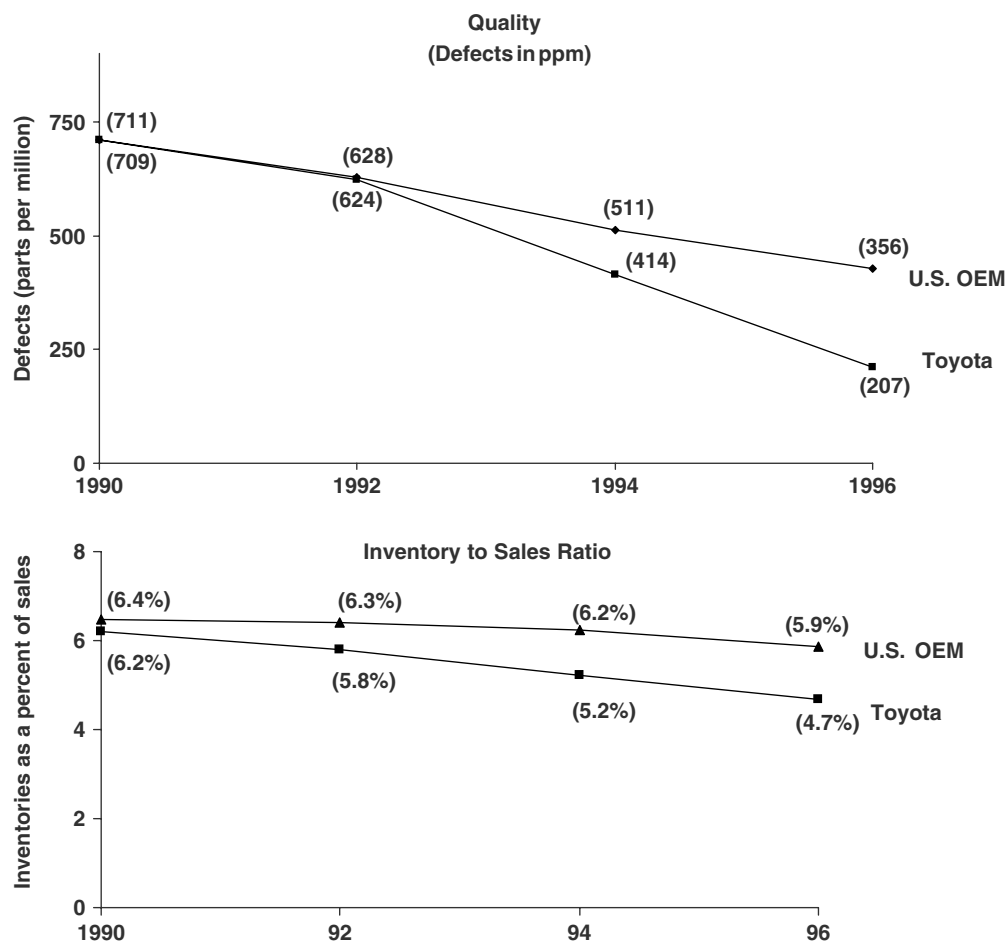


Figure 2. U.S. supplier performance over time (for Toyota vs. the supplier's largest U.S. OEM). Note: Results are based on weight averages versus as reported in Table 1

Table 2. Correlation matrices for Model I and Model II

	<i>dDefects-Change</i>	<i>dInventory/SalesChange</i>	<i>dFace-Days</i>	<i>dQuality-Assistance</i>	<i>dInventory-Assistance</i>
<i>dDefectsChange</i>	1.000				
<i>dInventory/SalesChange</i>	0.019	1.000			
<i>dFaceDays</i>	-0.358**	0.138	1.000		
<i>dQualityAssistance</i>	-0.402***	-0.378**	0.302*	1.000	
<i>dInventoryAssistance</i>	-0.240	-0.329**	0.212	0.430***	1.000

Correlation is significant at the *** $p < 0.01$ level; ** $p < 0.05$ level; * $p < 0.10$ level

All variables are the *difference* in knowledge-sharing activities and performance for Toyota vs. the supplier's largest U.S. customer.

Table 2 presents the correlation matrix for the dependent and independent variables used in the regression equations shown in Table 3. An examination of Table 2 indicates that the knowledge-sharing variables (*dFaceDays* and

dQualityAssistance or *dInventoryAssistance*) have a significant positive correlation. This should not be surprising since the information provided by each of these knowledge-sharing variables is somewhat redundant with the information

Table 3. Results of regression analysis: difference in knowledge-sharing activities on defects change and inventory/sales change

Explanatory variables	Model I <i>dDefectsChange</i>	Model II <i>dInventory/SalesChange</i>
Constant	−0.101 (0.068)	−0.079** (0.035)
<i>dOEMFaceDays</i>	−0.007* (0.004)	−0.001 (0.002)
<i>dQualityAssistance</i>	−0.057** (0.026)	
<i>dInventoryAssistance</i>		−0.021* (0.011)
<i>R</i> ²	0.223	0.113
<i>F</i>	5.55***	4.74**

Values in parentheses are standard errors.

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

available from the other variables (we would expect more days of face-to-face visits to translate into reports of greater knowledge acquired to improve quality or reduce inventories). As a result of high multicollinearity among the independent knowledge-sharing variables, a regression model that includes all three variables may very well lead to imprecise estimates of regression statistics. To respond to that concern, we share the regression results for each independent variable separately.

Table 3 presents the multivariate regression results with *dDefectsChange* and *dInventory/SalesChange* as the dependent variables in Models I and II. In these regression equations, the difference in face days (*dFaceDays*) has a positive influence on rate of performance improvement in both defects and inventory/sales, though it is only significant for defect changes (*dDefectsChange*, see Models I and II). The results show that when Toyota spends relatively more time exchanging knowledge at a supplier's plant, the supplier's performance improves at a faster rate for Toyota. We find that *dQualityAssistance* has a significant negative relationship with *dDefectsChange*, meaning that the greater quality assistance on the part of Toyota generates significantly faster reductions in defects for manufacturing cells dedicated to Toyota. We also find that *dInventoryAssistance* reduces inventory costs at a significantly faster rate in cells dedicated to Toyota (*dInventory/SalesChange*).

Several alternative explanations may also explain the defect and productivity improvements rather than the knowledge transfer processes we propose. For example, it could be argued that Toyota designs superior parts with lower defects. If that were true, the manufacturing cell would be expected to start at superior levels (relative to cells for U.S. OEMs) and then have only average rates

of improvement. Instead, as shown in Figure 2, we see that cells dedicated to Toyota start at almost identical levels and improve at significantly greater rates.

Another possible explanation of the defect and productivity improvements that does not require knowledge transfers is that the manufacturing cells supplying Toyota are on the earlier (steeper) stages of their learning curves. If this were true, supplier cells dedicated to Toyota would appear to improve at a faster rate in a given period of time even though the overall learning rate is the same. We find this explanation highly unlikely. The average life of a part is approximately 5 years for a U.S. OEM and 4 years for Toyota.⁵ In 1990, there would have been parts in the early stages, middle stages, and late stages for parts produced for U.S. OEMs and parts in the early and middle stages for parts produced for Toyota. By 1996, there are parts in all stages of the learning curve for both customers. It appears that any bias toward early stages in the learning curve for parts for Toyota would be minimal.

To summarize, on average, suppliers improve their performance (on quality and cost) at a faster rate for the customer that engages in greater knowledge-sharing initiatives. Thus, the results support Hypotheses 1 and 2.

RESULTS: EXPLORATORY STUDY

Our empirical results provide evidence not only that Toyota's knowledge transfers improve supplier performance, but also that the advantages

⁵ The average part life tracks the average model life, since parts are typically redesigned with each model redesign.

are sustainable. After 6 years of knowledge transfers, we see that the manufacturing cells dedicated to U.S. OEMs are not catching up. In fact, the gap in performance is widening. This shows that there must be barriers to replicating Toyota's relational advantages for U.S. OEMs. However, these results do not reveal *why* suppliers struggle to transfer knowledge to improve their performance in manufacturing cells dedicated to Toyota's rivals. To shed light on the barriers to replication, we randomly selected 13 suppliers and conducted in-person interviews to learn more about their performance improvements and obstacles to replicate them in other cells.

All of these suppliers claimed that they learned more from Toyota than their U.S. customer. Moreover, 10 of the 13 suppliers claimed that their cost and quality performance was superior for Toyota (the other three indicated no differences). As the Vice President of Planning at a supplier of plastic interior parts observed:

I couldn't believe it but Toyota sent approximately 2–3 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. We've reduced set up times from 50 minutes to 10–15 minutes and cut inventories by 80 percent. Our plant was originally designed for 3–4 presses but it now houses 23. We couldn't have done it without Toyota. (Interview, November 6, 1999)

Stated another plant manager:

With Toyota's help we redesigned our production process. We eliminated three forklifts by using wheels on carts to stack our product. We eliminated conveyor belts. We dramatically cut inventories. Ninety percent of everything we have learned from our customers, we've learned from Toyota (Interview, September 5, 1997).

Finally, the plant manager of a supplier of stamped parts stated:

We reduced our process steps from 34 to 14, eliminating 20 non-value added process steps from our production process. We reduced set-up times from 2 hours to 15 minutes, and we cut our inventory to almost 1/10 of previous levels. (Interview, November 19, 1996)

The plant managers were unanimous in their opinion that Toyota provided more assistance than their largest U.S. customer and that this knowledge was important in helping them improve performance.

Barriers to knowledge transfers within plants

We now turn to the question of why cost and quality differences may persist within the same plant. To explore why plant managers did not immediately transfer the improved processes to other manufacturing cells within the plant, follow-up interviews were conducted with our subset

Table 4. Summary of plant manager interviews on barriers to intra-plant knowledge transfers

Supplier #	Supplier product(s)	Better performance for Toyota	Network constraints reported as a barrier to transfer	Process rigidities reported as a barrier to transfer
1	Metal body stampings	Yes	Yes	Yes
2	Windshields	Yes	Yes	Yes
3	Steering system components	Yes	Yes	Yes ^b
4	Modular windows	Yes	Yes	Yes
5	Suspension struts	Yes	Yes	Yes ^a
6	Steel forgings	Yes	Yes ^a	Yes
7	Cam shaft drive timing belt	Yes	Yes	Yes ^a
8	A/C outlets, I. P. Trim	Yes	Yes ^a	Yes ^b
9	Wheel trim	Yes	No	Yes
10	Leather for seating	Yes	No	Yes
11	Wheel bearings	No	No	No
12	Interior trim (headlines, mirrors)	No	No	No
13	Floor carpet	No	No	No

Responses were unprompted unless otherwise indicated.

^a Respondent agreed that this was a barrier to knowledge transfer after being prompted by the interviewer.

^b Respondent reported some concerns about his firm's ability to replicate the knowledge in other production cells without Toyota's assistance. Thus, in these two cases causal ambiguity or lack of absorptive capacity may be considered to be a barrier to replication.

of 13 suppliers, 10 of which reported significant within-plant differences and three of which did not (see Table 4 for an overview of the qualitative results). We added suppliers using a grounded theory snowball technique, and discontinued the interviews when the final three suppliers reported no new additional insights regarding barriers to knowledge transfers. Through these exploratory interviews, we identified two key barriers to intra-firm knowledge transfers related to context that have not been empirically addressed in prior studies.

Network constraints

In 8 out of 13 interviews the plant manager reported being unable to transfer the knowledge employed in one manufacturing cell to another cell due to 'customer policies' or 'constraints imposed by the customer.' For example, customers sometimes dictate requirements to the supplier with regard to the production process and simply do not allow the supplier to easily change the process. To illustrate, one supplier was required by General Motors (GM) to use large (approximately 4' × 5') reusable containers. When filled with components, these containers weighed 200–300 pounds. By comparison, Toyota had the supplier use small (2' × 3') reusable containers weighing 40 pounds when filled. This one difference

immediately created a number of changes in the production process. The process for GM required significantly more floor space owing to the size of the containers. The supplier needed to purchase forklifts and hire forklift operators to move the containers. The large containers were more difficult to handle and keep clean, which affected product quality. The large containers also made it more difficult to label and sort products into a particular sequence for production at GM's facility. Because the large containers fit well into GM's system (which also used forklifts and lots of floor space) GM was not willing to allow the supplier to change the process. Thus, the supplier was unable to imitate the processes used in its Toyota manufacturing cells because the supplier's operations represented one element or stage within a production network. The ability to change processes in that one node (stage) of the network was constrained by that node's connections to other parts of the network.

Plant managers reported that their ability to implement Toyota Production System techniques was often constrained by customer policies/behavior. To illustrate, we found that suppliers are better able to keep inventories low in their Toyota manufacturing cells because Toyota's production forecasts only fluctuated 3 percent during the final 3 days before production. In contrast,

Table 5. Examples of customer practices that impose constraints on the supplier

Customer policies/practices that impose constraints	GM/Ford/Chrysler	Toyota
1. <i>Customer order fluctuation</i>	<i>N</i> = 18	<i>N</i> = 18
Percent deviation from schedule:		
• 2–3 days before needed	18%	3%**
• 1 day before needed	10%	2%**
2. <i>Customer delivery requirements</i>		
• Percent of suppliers who say the customer imposes a penalty for not filling up a truck	44%	5.5%**
• Percent of shipment volume fluctuation in a week	25%	6%**
• No. of shipments made daily	2.2	5.4**
3. <i>Trucking practices</i>		
• No. of truckers used	3.8	1**
• Loading time (minutes)	50	32**
• Percent side-loading trucks/trailers	0%	70%**
• Percent on-time pick-ups achieved	82%	94%**

For similar results with a larger sample, see Wu and Liker (1999).

** $p < 0.01$

Results are based on a survey of 18 of the original 45 suppliers that responded to the survey.

Ford and GM's forecasts fluctuated by 18 percent during the final 3 days before production (see Table 5; also see Wu and Liker, 1999). In addition, U.S. automakers were more likely to require that suppliers ship full trucks, thereby forcing suppliers to hold more inventories. Furthermore, U.S. automakers used numerous trucking companies that were less likely to arrive on time for pickup and who do not have side loading capability. In contrast, Toyota uses only one trucking company with side-loading trailers, thereby reducing the time spent loading the truck. This practice speeds through-put of inventories throughout the production network. Table 5 offers a summary of some customer policies that constrain the supplier's ability to use the same production processes for all customers. In addition to the above-mentioned policies, supplier executives claimed that whenever they wanted to make a major process change they had to get approval from the customer. Because these approvals were time-consuming and difficult to get, many times plant managers simply avoided 'the hassle.' Unless the other customers change their policies and systems, the production capabilities developed by suppliers may be relationship-specific.

While it may seem irrational for an automaker to prevent a supplier from adopting seemingly superior production routines, this behavior is quite consistent with the viewpoint on organizations that is basic to the evolutionary economic theory developed by Nelson and Winter (1982: 116):

Modifications of routine that involve improvements in role performance are presumably welcome. However, in functioning complex systems with many highly differentiated and interdependent parts, it is highly unlikely that undirected change in a single part will have beneficial effects on the system . . . changes that seem like obvious improvements viewed from a particular role can easily have adverse effects elsewhere in the system.

Thus, it may be rational for U.S. automakers to prevent suppliers from making changes if the benefits of those changes are only realized if the automaker simultaneously makes costly changes to its intra-and inter-organizational routines.

Internal process rigidities

In addition to facing *network constraints*, 10 out of 13 suppliers reported that they did not transfer

the knowledge gained from Toyota due to manufacturing *process rigidities* in the layout of the manufacturing cells for the U.S. customer. They were much less likely to attempt to transfer the knowledge when the U.S. customer's production process involved a high level of automation or large capital investment in heavy equipment. In some cases the large machines and equipment were bolted or cemented into the floor, there was trenching in the floor, or the utilities were hardwired to the machines. Consequently, there were process rigidities within those manufacturing cells that increased the costs of change. As one plant manager reported, 'When you invest in automation, you do everything you can to run that job for as long as you can. When you have to change a highly automated process you have a devil of a time. It just never works.' In contrast, Toyota's production network is designed as a dynamic system, and the flexibility to modify the system is built into the processes and procedures. Suppliers use more 'mobile' machinery (to allow reconfiguring the manufacturing cell) in their Toyota cells compared to their GM/Ford cells (Wu and Liker, 1999). This may explain why suppliers had relatively low rates of labor productivity improvement for their U.S. customers. These process rigidities resulted in plant managers waiting until the vehicle model change before implementing a new process. Thus, at the very least internal process rigidities created a significant time lag before the new processes were implemented.

In addition to network constraints and process rigidities, 2 of 13 suppliers admitted concerns about their 'ability' to replicate the knowledge in their other manufacturing cells. We view this as either 'causal ambiguity' or lack of absorptive capacity (Szulanski, 1996). The combination of network constraints, process rigidities, and causal ambiguity/absorptive capacity barriers created risks for suppliers who wanted to transfer the knowledge. For example, the president of one supplier argued:

The Toyota Production System is a very fragile system that requires constant attention. One person can make a minor change and it can mess up the whole system. This is a real problem in dealing with [our U.S. customer]. Any time we want to change the process, we must follow a set of bureaucratic rules . . . if you make a change that causes a problem and you've not followed their procedure exactly, then you have a huge liability. If you cause

a recall, or even if they think you caused a recall, it could put you out of business. And if you shut down their plant they charge you \$30,000 a minute. Sometimes it's just not worth the risk (Interview, February 25, 1998).

Finally, suppliers who more frequently reported barriers to knowledge transfers produced components that were more likely to be tailored to the specific vehicle model (e.g., metal body stampings, steering system components, windshields). When the component was more commodity-like (e.g., carpet, trim, wheel bearings, leather), suppliers reported fewer barriers to transfer (See Table 4). Thus, the ability to create advantage by exploiting knowledge assets with suppliers is likely to be greater for products comprised of inputs that tend to be highly customized (e.g., complex, highly integrated, closed architecture products such as autos, aircraft, robotics, or machine tools).

A model of barriers to intra- and interfirm knowledge transfers

Our study provides a more comprehensive model of how context is a barrier to knowledge transfers (see Figure 3). The barriers to knowledge transfer identified in prior studies are attributes of the *source* of knowledge (e.g., lack of motivation, lack of credibility), attributes of the *recipient* of knowledge (lack of absorptive capacity, lack of motivation), or attributes of the knowledge itself (causal ambiguity). However, the barriers identified in this study are external to the source, recipient, or knowledge itself. The knowledge transfer does not take place due to (1) network constraints, or (2) an existing process with rigidities that make adoption of the new process difficult or costly.

Moreover, even when there is only a low probability of failure, suppliers may refuse to attempt the knowledge transfer because the costs associated with failure are so high. These contextual barriers to *intra*-firm knowledge transfers preserve the quality advantages for Toyota.

Toyota's quality advantages contribute to an average 9.7 percent price premium in new cars, and 17.6 percent premium in used cars relative to U.S. OEM cars in the same car class (see the Appendix). Toyota's price premium is due in part to the quality advantages generated through its knowledge transfer activities, which costs an estimated \$75–100 million in the United States and Japan. The quality differences reported in this paper are consistent with data from J. D. Power's Initial Quality study, which found that in 1996 Toyota had 65 problems per 100 vehicles compared to 119 problems for GM, Ford, and Chrysler (*Automotive Industries*, April 13, 1996; JD Power Initial Quality Study). Toyota may also realize cost advantages through its suppliers. However, without specific component price information for each customer, which suppliers were unwilling to provide, we cannot empirically demonstrate a cost advantage for Toyota. However, the fact that Toyota's net profits exceeded the *combined* 2003 profits of GM, Ford and Daimler-Chrysler suggests that Toyota probably also generates cost advantages through their knowledge-sharing activities.

CONCLUSION

As U.S. OEMs look to Toyota for insights into improved performance, one well-known resource

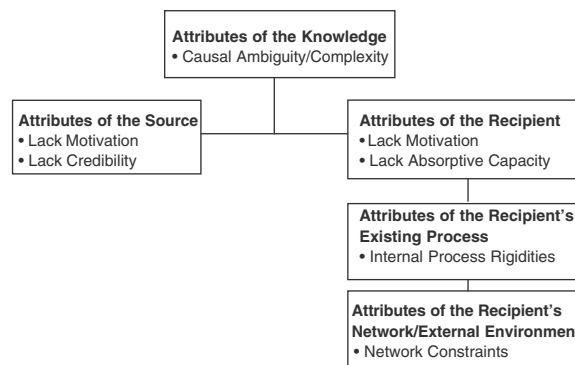


Figure 3. Barriers to knowledge transfers

is the 'Toyota Production System,' which includes a cultivated network of learning and knowledge sharing between Toyota and its suppliers. The benefits of TPS include higher-quality automobiles that earn price premia as well as flexible manufacturing systems that allow cost-effective customization (quickly switching between models as preferences change). By teaching the Toyota production system to its U.S. suppliers, Toyota appears to be handing over the keys to the vault, but the U.S. automakers are not opening the door. Why not? Our research suggests that the costs of a wholesale implementation of the Toyota production system may outweigh the benefits. To allow suppliers to use Toyota's methods (and expropriate the rents Toyota earns) the U.S. OEMs would often have to rework their entire production system.

The findings from this study indicate that a firm can achieve relational competitive advantage (e.g., superior quality) by leveraging its knowledge assets with its supplier network. Moreover, firms may exhibit *differential* performance as members of different networks. These findings are important because they provide evidence that:

1. *Networks are a critical unit of analysis for explaining firm performance, even when networks appear to be similar.* Network theory suggests that firms with structurally equivalent networks should realize similar benefits through those networks. Our study showed empirically that firms with structurally equivalent (supplier) networks can still achieve differential benefits through those networks. This provides powerful evidence for the contention that 'the conduct and performance of firms can be more fully understood by examining the network of relationships in which they are embedded' (Gulati *et al.*, 2000: 203). If firms can generate competitive advantage through equivalent supplier networks then certainly the potential is even greater for differentiated networks. Thus, this study offers empirical support for the importance of studying networks to understand firm performance (Dyer and Singh, 1998).
2. *Firms (with useful knowledge) can achieve competitive advantages by exploiting those knowledge assets with a supplier network.* Indeed, knowledge transfers from customers to suppliers can build relationship-specific production capabilities on the part of suppliers. This leads
3. *Network constraints represent a potential barrier to knowledge transfer within firms, especially within a value chain producing a customized, complex product.* Our results offer a more comprehensive understanding of the 'context' barriers to knowledge transfers (Rivkin, 2001). We find that barriers exist even when the source and recipient of knowledge are motivated and the recipient has the necessary absorptive capacity. The advantages that Toyota realizes by transferring knowledge to its suppliers are preserved due to barriers associated with (1) one phase of *knowledge transfer* (the supplier must transfer the knowledge within its plant), and (2) a separate phase of *knowledge imitation* (the other customer must imitate Toyota's inter-organizational routines with suppliers in order to benefit from Toyota's network resources). Knowledge does not flow from Toyota's production network to GM's production network without requiring simultaneous changes throughout the entire GM network. Network-level barriers to intra-firm knowledge transfers preserve the competitive advantages that can be achieved through interfirm knowledge transfer routines. This study demonstrates that networks are an important unit of analysis

in strategy research and that firms can create advantages by leveraging knowledge assets within networks of relationships.

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Appendix: Toyota Quality Price Premium (Highest Volume Car classes*)

Toyota Price Premium Over Average Competitor in Class

Car Class	Model	J.D. Power Top 3 Quality Rank (2002)	Toyota Retail Price Premium ¹	Toyota Used Car Price Premium ²	Unit Sales Volume Premium ³
Compact Sedan	Corolla	1	13.0%	8.1%	69.0%
Midsized Sedan	Camry	Not Ranked	18.8%	15.6%	195.5%
Compact Pickup	Tacoma	1	1.3%	48.0%	7.9%
Full-size Pickup	Tundra	1	-10.1%	-4.1%	-81.1%
Compact SUV	RAV4	1	-9.3%	11.7%	14.7%
Midsized SUV	4Runner	2	16.5%	16.9%	-28.0%
Compact Van	Sienna	1	7.2%	28.4%	79.7%
Average Premium ⁴			5.3%	17.8%	36.8%
Sales Volume Weighted Average Premium ⁵			9.7%	17.6%	86.2%

Comparison cars in each class:

Compact Sedan: Chevrolet Cavalier, Pontiac Sunfire, Saturn S-series, Saturn Ion, Dodge Neon, Ford Focus, Ford Escort

Midsized Sedan: Buick Century, Chevrolet Malibu, Pontiac Grand Prix, Dodge Stratus, Chrysler Sebring, Ford Taurus

Compact Pickup: GMC Sonoma, Chevrolet S10, Dodge Dakota, Ford Ranger

Full-size Pickup: Chevrolet Silverado 1500, Chevrolet Silverado 2500, GMC Sierra 1500, GMC Sierra 2500, Dodge Ram 1500, Ford F-150

Compact SUV: Chevrolet Tracker, Jeep Wrangler, Jeep Liberty, Saturn VUE, Ford Escape

Midsized SUV: GMC Envoy, Chevrolet TrailBlazer/Blazer, Buick Rendezvous, Oldsmobile Bravada, Pontiac Aztec, Dodge Durango, Jeep Grand Cherokee, Ford Explorer, Mercury Mountaineer

Compact Van: Chevrolet Astro, Chevrolet Venture, GMC Safari, Pontiac Montana, Oldsmobile Silhouette, Chrysler Town and Country, Chrysler Voyager, Dodge Caravan, Ford Windstar, Mercury Villager

Notes:

¹ Toyota model average retail price premium over average competitor retail price. Average retail price calculated as average of high and low MSRP range, less cash rebates, as reported by MSN auto, April 2003

² Toyota model average used price premium over average competitor used price, for models three years beyond 2003 model year (2000 model year). Average used price calculated as average of high and low *Kelley Blue Book* values as reported by MSN auto, April 2003

³ Toyota model U.S. sales volume premium over median competitor U.S. sales figures drawn from *Automotive News Market Data Book* 2002, 2000 and Automotive YTD Sales Data as reported in *Automotive News*, January 6, 2003

⁴ Calculated as a straight arithmetic average of the listed models

⁵ Calculated as an arithmetic average of listed models weighted for the proportion of U.S. sales volume for models listed

* In the 9 car classes not included (sports, luxury, large vehicles) Toyota was #1 in quality in 4 of the 9 classes, number 2 in one class, and number 3 in one class.