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COLLABORATION AND TECHNOLOGY LINKAGES: A STRATEGIC SUPPLIER TYPOLOGY

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This study uses frameworks from the strategic management and operations strategy literatures to explore the relationships among collaboration, technology, and innovation in small and medium-sized manufacturers. Statistical analysis of the responses of 200 New Hampshire manufacturing companies in four SIC code industries (fabricated metals, industrial equipment, electrical and electronic equipment, and instruments) leads to the development of a strategic supplier typology which is useful in explaining the differences in the composition and performance of various types of suppliers. Copyright © 2000 John Wiley & Sons, Ltd.

INTRODUCTION

A large and diverse literature now exists on interfirm cooperative relationships (Pfeffer and Nowak, 1996; Buckley and Casson, 1996; Mariti and Smiley, 1996; Kay, 1997; Casson, 1998; Dyer and Singh, 1998). This literature has gained such prominence that it now stands as one of three ways to understand how firms sustain profits or quasi-rents. The first way to account for quasi-rents is to focus on industry characteristics, particularly how an industry gains bargaining power over suppliers and customers (Rumelt, Schendel, and Teece, 1991). The second way focuses on how individual firms efficiently or inefficiently manage their resource base (Chandler, 1977; Rumelt, 1984). Originally, resource-based economists spoke of the heroic entrepreneur who brazenly proclaimed uncertainty to be opportunity and profits the pay-off for those who succeeded (Knight, 1921). Even when economists acknowledged that large firms internalized this entrepreneurial function in research and development units, innovation remained confined to the firm's actions (Von Hippel, 1998; Utterback, 1994; Hughes, 1989; Chandler, 1977).

The relation-based view similarly begins with the firm. However, this view posits that firms may improve their ability to engage in process and product innovation by carefully managing their relationships with suppliers, customers, and other resource providers such as universities or government agencies. The relation-based school thinks of innovation as a highly structured activity embedded in networks that span organizational and geographic boundaries (Aoki, 1984; Helper and Levine, 1992; Nishiguchi and Anderson, 1995; Kay, 1997; Nelson and Wright, 1992; Nelson, 1993; Baumol, Nelson, and Wolff, 1993; Mowery and Rosenberg, 1998; North, 1990; Galambos and Sewell, 1995; Sapolsky, Gholz, and Kaufman, 1999; Rosenblum and Spencer, 1996). These scholars ask whether an innovation is firm-specific or -dependent in interorganizational relations; whether the innovation enforces or unmakes existing networks; and whether it is continuous or discontinuous. If the innovation

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depends on relations with other organizations, these scholars speak of quasi-rents as relational rents (Dyer and Singh, 1998).

Strategic and operations management scholars have drawn on this literature to reexamine supply chain relationships (Kamath and Liker, 1994; Bensaou and Venkatraman, 1995; Nishiguchi, 1994; Dyer and Singh, 1998). Where scholars once argued that a firm may either make a product or service themselves or buy it through the market (Coase, 1988; Williamson, 1985; Chandler, 1977), they now argue that firms have a third alternative: structuring as long-term relationships with suppliers which more closely resemble 'partnerships' than market transactions (Blois, 1996; Kay, 1997; Casson, 1998). These partnerships succeed when they develop idiosyncratic interfirm relations through investments in specific capital assets, shared know-how, complementary assets, and effective governance mechanisms (Dyer and Singh, 1998; Gulati, 1995; Williamson, 1985).

Because large original equipment manufacturers (OEMs) have driven this process, most studies have examined these firms' strategic and structural reasons for remaking their supplier chains. Scholars account for the growing presence of the relational alternative by citing: (1) how Japanese competitors have made market gains by managing their supplier relationships as 'quasi-partnerships' (Dertouzos, Lester and Solow, 1989; Womack, Jones and Roos, 1990; Smitka, 1991; Nishiguchi, 1994; Shiba, 1997); and (2) how modern information technologies have promoted flexible manufacturing systems that substantially reduce transaction costs and allow managers to harness market efficiency (Adler, 1988; Argyres, 1999). For example, market-based alternatives to vertical integration may be more conducive to product and process innovation. This research has led many to reexamine the 'mechanics' of supply chain relationships (Quinn and Hilmer, 1994; Bensaou and Venkatraman, 1995; Nishiguchi, 1994; Dyer and Ouchi, 1993; Smitka, 1991). In the automobile industry, one research group has described a Japanese variant—lean manufacturing—as superior to America's mass production system (Womack *et al.*, 1990). And another research team commissioned by the U.S. Air Force has examined ways to develop lean manufacturing in the defense aircraft industry (Reynolds and Bozdogan, 1995).

A parallel, smaller literature has examined how small and medium-sized manufacturers (SMMs) fit within this restructured vertical supply chain or network (Rothwell and Dodgson, 1991; Lefebvre, Langley, Harvey and Lefebvre, 1992; Wood, Kaufman, and Merenda, 1996; Kaufman, Merenda, and Wood, 1996). A consensus has emerged on SMM supply chain engagement, namely that these manufacturers rarely use modern information technologies or managerial techniques to form the complex 'horizontal' interfirm relationships that aggregate into global networks or business groups (Kay, 1997; Harrison, 1994; Nishiguchi and Anderson, 1995). Instead, SMMs have reconnected to OEMs as these firms have used modern technologies and techniques to reconsider earlier make-or-buy decisions and to reorganize their supply chains. Few have examined how OEMs and suppliers devise search methods for complementary 'partners,' and few have explored the organizational structure and decision patterns that these SMMs use to pursue long-term viability (Lassar and Kerr, 1996; Blois, 1996; Dyer and Singh, 1998). We take up these questions by first elaborating a strategic supplier typology, which we construct using transaction cost economics principles. This typology provides categories which OEMs can use to determine what type of supplier to engage. At the same time, it describes alternative strategies that suppliers can adopt. After elaborating these strategic options, we empirically examine how effectively our typology accounts for SMM strategic actions.

LITERATURE REVIEW AND RESEARCH QUESTIONS

Our study begins with Clark and Fujimoto's (1991) study of auto manufacturers. They offer an interesting approach to classify OEM suppliers by the auto industry's product development process. Clark and Fujimoto observed that automotive OEMs divided purchased component parts (and their manufacturers) into three categories: black box parts, detail-controlled parts, and supplier-proprietary parts (Clark and Fujimoto, 1991: 140–143). Though useful, this has three weaknesses: (1) it considers the supply as a single link between the OEM and a supplier; (2) it ignores the SMM as an active, albeit junior, participant in the process; and (3) it provides a sparse taxonomy of SMM strategies rather than a systematic typology.

Taxonomy vs. typology

Classification schemes have gained substantial popularity in developing analytical frameworks to understand how firms compete (Burns and Stalker, 1961; Woodward, 1965; Miles and Snow, 1978; Galbraith and Schendel, 1983). The corporate strategy literature contains numerous methodological reviews of organizational classifications (McKelvey, 1975; Carper and Snizek, 1980; Hambrick, 1983; Miller and Friesen, 1984; Bensaou and Venkatraman, 1995). This literature has provided unambiguous definitions for two general forms of classification schema: taxonomy and typology. A *taxonomy* uncovers patterns within a set of variables creating interesting but theoretically unsupported clusters or groups. A *typology* begins with theory: it specifies combinations of variables for testing *a priori* generated conceptual types (Miller and Friesen, 1984: 31–36).

Transaction cost economics

The make-or-buy decision provides transaction cost economics with its basic unit of analysis (Buckley and Michie, 1996; Walker, 1988; Teece, 1986; Williamson, 1985). This literature has become extremely complex and somewhat controversial (Kay, 1997; Ghoshal and Moran, 1996; Englander, 1988; Walker, 1988). Nonetheless, transaction cost economics provides helpful theoretical constructs for building a strategic supplier typology. Transaction cost economics tells us that the decision to vertically integrate depends on the relative monitoring costs that arise from the inability to make perfect decisions (bounded rationality) and from the uncertainty which arises when the firm must trust a self-interested external agent (opportunism). These costs increase when the firm frequently requires large amounts of work for which specific assets are necessary (Williamson, 1985). Divergent strategic interests require the use of complex and expensive governing procedures to monitor information and enforce promises (Dyer and Singh, 1998).

Transaction cost economics and the strategic management literature recognize numerous categories of uncertainty such as environmental, partnership, and task (in Bensaou and Venkatraman, 1995; Thompson, 1967; Milliken, 1987) or specific capital assets, shared know-how, and complementary assets (in Dyer and Singh, 1998). However, we take the simpler approach and deal with all types of uncertainty as an asymmetric information problem as in Cheung (1983), Coase (1988), and Fransman (1994). Our typology rests on dealing with two types of information uncertainty arising from relation-specific investments in physical and human capital—holdup and information leakage. When these uncertainties become transformed into manageable risk, the OEM is able to *collaborate* with an SMM in defining product and process problems and in designing *technical production* solutions (see 'Conceptualizing a strategic supplier typology' below).

Transaction costs and vertical integration

OEMs compete in product markets on price, quality, and delivery times. To succeed, managers define: (1) the firm's in-house know-how that makes it a unique provider in terms of price, quality, and product development; and (2) the assets which are essential to sustain and develop the firm's core capabilities (Prahalad and Hamel, 1990; Leonard-Barton, 1992; Schoemaker, 1992; Walker and Poppo, 1991; Quinn and Hilmer, 1994; Venkatesan, 1992; Nishiguchi, 1994; Teece, 1997; Quinn, Anderson, and Finkelstein, 1997). By know-how we refer to the noncodified knowledge and procedures that employees gain by working in the firm's structured setting as team members. Scholars generally divide knowledge into two categories (Von Hippel, 1988; Nelson and Wright, 1992; Dyer and Singh, 1998; Von Hippel, 1998; North, 1990; Doz and Hamel, 1997). The first, codified information, refers to knowledge that can be easily elaborated in manuals and other educational materials. Since this form of knowledge spreads rapidly, firms cannot turn it into rent-garnering idiosyncratic skills. The second form of knowledge, know-how, cannot be written on paper. It is produced by experience and social interactions that are not readily duplicated. Thus, know-how is tacit, 'sticky' knowledge that firms can foster for competitive advantage (Von Hippel, 1988; Grant, 1996; Mowery, Oxley, and Silverman, 1996). Because know-how happens as a cumulative learning process, firms compete in an evolutionary way where successes and failures, if handled properly, enhance team know-how (Tyre and Orlikowski, 1993; Burgelman and Rosenbloom, 1989).

OEMs gain cost and quality advantages when they encourage production teams to seek out ways to continuously improve quality and reduce costs. And, when OEMs combine this know-how with design and product development teams, these firms may reduce product cycle times and gain competitive advantage (Sanderson and Uzumeri, 1995; Clark and Wheelwright, 1992; Ancona and Caldwell, 1997; Nonaka, 1990). Firms which assemble such teams gain substantial 'learning momentum' that distances them from competitors who have not achieved 'learning economies' (Gomory, 1992; Quinn *et al.*, 1997). If managers outsource these activities, they risk hollowing out the firm's core competencies, transferring specialized skills to potential rivals, and being subject to holdup (Teece, 1997; Walker and Poppo, 1991).

However, when activities do not fall within the firm's core competencies (or if a part is not critical to the assembly process), managers must decide whether it is more economical to make or to buy the parts, i.e., whether the costs of producing a part are less than the costs of writing, monitoring, and enforcing contracts. This exercise, like that of identifying a firm's core and complementary competencies, cannot be reduced to a comparison of administrative and legal costs. Market transactions and hierarchy offer different ways of governing inter- and intrafirm relations. Take the simple case of a firm with daily operations that require standard parts for which there are many suppliers. Here normal market transactions suffice. The parts do not embody specialized know-how that differentiates the product.

But the market does not function so well when (1) parts are highly specialized and few suppliers have the skill to manufacture them and (2) the customer demands that these parts be continuously improved to sustain competitive advantage. In these situations, hierarchy prevails because it allows for future decisions. It allows managers and employees to innovate and to act as teams to redesign parts and subsystems and integrate systems in a 'relatively' spontaneous way (Kay, 1997).

Transaction cost economics and strategic outsourcing

The make-or-buy proposition implies that nondetailed components should be produced in-house because market boundaries do not allow for interfirm team relationships. Until recently, most scholars agreed with this proposition (Chandler, 1977). But Japanese supply chain management has undone this former convention. Japanese firms have outsourced noncore competence activities and required that suppliers invest in relation-specific physical and human capital (Nishiguchi, 1994).

When an OEM demands that an SMM make relation-specific investments to satisfy the OEM's specialized component needs, both parties find themselves in a mutually dependent situation which either can easily abuse (Dyer and Singh, 1998). Once the SMM makes relation-specific investments to satisfy its OEM customer, the OEM faces high switching costs, i.e., in locating and contracting with another supplier. Likewise, the supplier faces high switching costs in locating a new customer with needs for the assets and skills specific to a single customer's needs (Williamson, 1985).

Dependency arises as much from the specific knowledge that each party develops of the other as it does from specialized capital investments. An OEM and an SMM develop this tacit knowledge by engaging in collaborative practices such as concurrent engineering and personnel sharing. But there are risks to developing this know-how through interfirm relations. A customer may transfer this interfirm know-how to a rival supplier in order to minimize customer dependency or threaten such actions to hold up its partner. The supplier may act in a similar manner by threatening to seek out, or actually seeking out, new customers.

To minimize holdups and information leakage, the OEM and the specialized supplier must adopt governance procedures that convert uncertainty into manageable risk (Williamson, 1985; Klein, 1992). This may occur through formal governance structures (e.g., shared equity stakes) or informal mechanisms such as trust and reputation (Suzuki, 1997; Kester, 1991; Chiles and McMackin, 1996; Dyer and Singh, 1998; Barney and Hansen, 1994; Axelrod, 1984). For example, firms may agree to a long-term contract and share the investment cost in the relation-specific asset. Supplier certification establishes a method whereby OEMs and suppliers agree on the product and service aspects of their relationship: quality, delivery, and terms (Krajewski and Ritzman, 1996). Value engineering provides a procedure by which OEM and supplier can agree on cost reduction efforts and establish mechanisms such as target pricing to communicate systematic changes and gain sharing (Stevens, 1992; Cole, 1988; Nishiguchi and Anderson, 1995). And by transferring technology and personnel across firm boundaries, managers can build interfirm innovative teams (Dyer, 1996; Johnston and Lawrence, 1988).

Information technologies have increased the propensity for collaboration by allowing interfirm computer-integrated manufacturing (Adler, 1988; Chesborough and Teece, 1996; Argyres, 1999). Finally flexible manufacturing technologies allow SMMs to inexpensively modify production setups to meet a variety of specialized needs. When these interfirm teams are successful, they possess interfirm know-how with idiosyncratic character that allows the partnering firms to take full advantage of relation-specific investments (Dyer and Singh, 1998). When such practices are successfully repeated, they facilitate trust. And when successful, each 'partner' earns relational rents.

Repeated success minimizes the threat of holdup and information leakage. So do modern technologies. Flexible manufacturing and information technologies expand the supplier base available to an OEM and the customer base available to a supplier. This reduces switching costs and makes holdup uncertainty a manageable affair. However, switching costs remain higher than those found in competitive markets. Firms must be able to recognize complementary customers or suppliers, they must have overlapping skill sets that allow for communication, and they must repeat their transactions over a considerable period of time to form interfirm relational-rent know-how (Dyer and Singh, 1998; Gerwin, 1993; Rosenberg, 1961; Rosenbloom and Christensen, 1994). Thus OEM and SMM managers must calculate the costs and benefits of seeking alternative partners when considering the benefits of expanding the customer/supplier base or retaliating against a perceived wrongdoing.

Overall, strategic outsourcing produces the efficiencies inherent in a market division of labor. First, OEMs regain the market pricing mechanism to calculate costs. Vertical integration may reduce transaction costs but it creates a long-standing problem: how to accurately measure the costs of components produced in-house or determine a transfer price (Johnson and Kaplan, 1987). By divesting in-house tasks, managers gain market information about product costs. Even in situations where a firm relies on a single-source supplier, alternate market options exist even if switching costs are high. Flexible manufacturing promotes this trend since it allows suppliers to 'reprogram' production processes to meet OEM relation-specific needs.

Second, and more important, strategic outsourcing reinvigorates a market division of labor. OEMs can focus on those skills that distinguish them from competitors, while SMMs develop the know-how to design and manufacture components and subsystems. SMMs gain broad expertise when they serve a variety of customers whether in the same industry or diverse industries. The knowledge gained from working with one customer may develop skills for tackling problems with another customer. And OEMs leverage this supplier know-how when they organize interfirm teams to develop new products and reduce cycle times (Nonaka, 1990; Quinn *et al.*, 1997).

OEM strategic outsourcing and SMM opportunity

So far, we have maintained the OEM as the principal actor in strategic outsourcing. Large OEMs originated this process and have propelled it. Japanese OEMs undertook this process during the 1960s to promote product diversification. Faced with capital scarcity and public-financing policies favorable to SMMs, Japanese OEMs sold equipment to their suppliers and offered them training to diversify product offerings (Nishiguchi, 1994; Shiba, 1997; Ueda, 1997). As U.S. automobile, semiconductor, and electronics producers lost market share to Japanese competitors, U.S. companies began to imitate Japanese supply chain management policies and to develop strategic outsourcing procedures (Dertouzos *et al.*, 1989; Fransman, 1994; Grindley, Mowery, and Silverman, 1994).

These policies have opened new opportunities for suppliers willing to upgrade their capabilities. For those adventurous enough to chase these opportunities, strategic outsourcing becomes an effective competitive tool. It allows SMM managers to identify core competencies, outsource other activities, and use supply chain management techniques to leverage their assets and know-how.

CONCEPTUALIZING A STRATEGIC SUPPLIER TYPOLOGY

The application of these theoretical concepts to the supply chain allows for the construction of a supplier typology. This typology divides along two dimensions: technology and collaboration. By dividing these dimensions into high and low categories, we create four distinct supplier strategies (see Figure 1).

Quadrant I defines firms that use standardized technologies and relate to customers through standard market contracts. Typically firms in this space compete successfully on the basis of low cost: investments in advanced technologies and managerial practices usually cannot be fully recovered. Neither customers nor suppliers are dependent because switching costs are low. Parts are designed and manufactured to be sold 'out of the catalog' to a generic customer. We label firms in this quadrant *commodity suppliers* (CSs).

Quadrant II contains firms that use standardized technologies (general assets and skills) to make parts which meet customer specifications and delivery schedules. These firms develop enhanced collaborative techniques to fulfill current and to anticipate future customer needs. Because these products remain under their customers' detailed (design) control (Clark and Fujimoto, 1991), suppliers in this quadrant invest few resources to innovate in product or process technology, thus avoiding dependency on a few customers. Customers find these suppliers attractive because they reduce internal monitoring (administrative) costs. Clark and Fujimoto give the example of the Japanese *taiyo-zu* (provided drawings) system in their discussion of detail-controlled parts suppliers (Clark and Fujimoto, 1991: 143). These suppliers' customers reduce holdup uncertainty by only outsourcing parts that do not use core manufacturing know-how. We call firms in this quadrant *collaboration specialists.*

	COLLABORATION Low	COLLABORATION High
TECHNOLOGY Low	**I** **COMMODITY SUPPLIER** - Spot Market supplier - Low cost, low price priorities - Little or no differentiation n = 59 Av. No. of Employees = 28	**II** **COLLABORATION SPECIALIST** - Detail-controlled parts supplier - Uses a closed network in each industry - Can be in many industries to maintain customer product information n = 41 Av. No. of Employees = 150
TECHNOLOGY High	**IV** **TECHNOLOGY SPECIALIST** - Proprietary parts supplier - Innovation in product technology used to produce high barriers to entry - First mover advantages - Uses design capabilities for competitive advantage n = 35 Av. No. of Employees = 44	**III** **PROBLEM-SOLVING SUPPLIER** - Black Box supplier - High differentiation - Cost less important - Small runs, high process and labor flexibility n = 65 Av. No. of Employees = 260

Figure 1. Strategic supplier typology

Quadrant III describes firms that employ both advanced technologies and collaborative methods to promote innovations in product design and manufacture. Firms in this quadrant compete primarily on their ability to continuously acquire and evolve new ways to solve process and product problems (Clark and Fujimoto's black box suppliers). Customers reduce monitoring costs and avoid expensive investments in specific skills and assets. Because these firms become mutually dependent on one another, trust reduces holdup uncertainty. Producers of complex subassemblies for the computer industry illustrate this type of supplier. We call firms in this quadrant *problem-solvers* (PSs).

Quadrant IV includes firms that emphasize technology and develop weak relationships with customers. These firms invest heavily in firm-specific skills and assets for producing proprietary products (Clark and Fujimoto, 1991). These firms strive to produce products of the highest quality and performance that will attract customers and reduce their reliance on a few customers. Customers benefit from relationships with these suppliers by acquiring exceptional or even unique parts without making major, costly investments. So long as customers do not outsource strategic parts to these suppliers, the risk of holdup uncertainty remains manageable. Engineering-driven firms fall into this quadrant. We call these firms *technology specialists.*

OPERATIONALIZING THE STRATEGIC SUPPLIER TYPOLOGY

To operationalize the strategies theorized above, we worked from experience and the literature on corporate and operations strategy. The collaboration dimension ranges from spot market arm's-length transactions on the low end to long-term relational contracts. Long-term relations include such practices as certification, target pricing, incentive contracts, and interfirm concurrent engineering with both customers and suppliers. To facilitate these long-term external relationships, firms typically develop their own advanced management practices, which include strategic planning, quality practices, and employee empowerment programs. The technology dimension ranges from firms that struggle to maintain routine manufacturing practices on the low end to firms that take advantage of advanced manufacturing and design technologies on the high end.

Based on these dimensions, we considered the implications to firms located in the different quadrants of the typology and developed four hypotheses. To simplify this exercise, we constructed hypotheses only for the problem-solving quadrant. Firms in this sector develop relational-collaborative and -technology links with their customers. Consequently, these SMMs should have characteristics distinctive from firms in the other quadrants.

Because PSs need to retain technical personnel to interact with their customers and to keep abreast of the latest technological developments, they will tend to have more employees, i.e., be of larger size (Rothwell and Dodgson, 1991). The capital investments required to develop a PS also suggest that these firms will be relatively large. This leads to our first hypothesis:

Hypothesis 1: PSs will be larger—have more employees and greater sales volume—than suppliers using other strategies.

Because the new collaborative approaches and active technology involvement encourage relational physical and human capital investments, problem-solvers should generate relational rents. Also, PSs have governance structures that provide formal and informal mechanisms that promote trust and reduce risk. These too make it likely that PSs will earn relational rents (Aoki, 1984; Helper and Levine, 1992; Dyer and Singh, 1998). This leads to our second hypothesis:

Hypothesis 2: PSs will be more profitable than suppliers using other strategies.

Given that problem-solving firms have developed intricate networks and have mastered advanced information technologies, they are likely to be more successful in global markets than firms in the other quadrants (Porter, 1990; Kanter, 1995; Rommel *et al.*, 1995). This leads to our third hypothesis:

Hypothesis 3: PSs will have a higher percentage of their sales in exports than suppliers using other strategies.

Finally, innovative firms require well-trained employees to continually improve products and processes. These workers with their firm-specific capital should be able to bargain for wages higher than those found on the spot market (Aoki, 1984; Porter, 1990). This leads to our fourth hypothesis:

Hypothesis 4: PSs will pay higher wages than suppliers using other strategies.

While these hypotheses test only some selected characteristics of the strategic supplier typology related to PSs, they represent the main opportunities for SMMs created by OEM strategic outsourcing and stand as developed relational firms. These four hypothesized practices suggest that suppliers continuously upgrade their skills and assets to engage in relational-rent activities.

The survey

We can test these hypotheses either through observation or direct inquiry of firms. We chose direct inquiry and decided to use a telephone survey of SMM presidents and CEOs. The 'Quickview' manufacturing survey developed by the National Institute of Standards and Technology's (NIST's) Northeast Manufacturing Technology Center (NEMTC) and the New York State Department of Economic Development (1992) provided us with an instrument to collect data. Quickview asks questions about 10 different aspects of firm operations: administration/ management practices, human resources and personnel, market management, bidding/estimating and quoting, purchasing/vendor development, product design and engineering, operations management, manufacturing technology, maintenance/ housekeeping, and quality management. A 5-point ordinal scale ranging from 1 (never/not at all) to 5 (always/to a great extent) is used to answer all perceptual questions. Some objective background questions are also included. To this extensive survey instrument, we added an addendum that asked 21 detailed questions about geographic proximity and relationships to both customers and suppliers.

The sample: New Hampshire manufacturers

To empirically test our typology, we selected New Hampshire as our sample population. New Hampshire provides appropriate data for study because it has led the United States in productivity growth between 1977 and 1988 (Sum, 1995) and virtually all this growth was in manufacturing (Kaufman *et al.*, 1994). Moreover, SMMs populate those industries that led this exceptional growth.

We used a telephone survey to gather data on 200 firms in the leading manufacturing industries in New Hampshire (fabricated metals, industrial machinery and equipment, electrical and electronic equipment, and instruments) using the enhanced Quickview survey instrument. We only sampled firms with more than 10 employees. This left a population of 423 firms that produced a response rate for our survey of nearly 50 percent.

METHODOLOGY

To test the typology we chose those variables from the Quickview survey which measure the use of collaboration and technology. We selected 26 'candidate' variables from the survey data to represent the collaboration dimension and 22 candidate variables for the technology dimension. We then analyzed this data using correlation analysis, contingency table analysis (cross-tabulation), analysis of variance, and simple descriptive statistics. Finally, to interpret the underlying multivariate relationship between the two dimensions of the typology, we used maximum likelihood factor analysis.

Correlation analysis is used to analyze the bivariate relationships among measured variables and factors constructed as linear combinations of the measured variables. We employed contingency table analysis on the variables and factors that were split at the median in order to compare the characteristics of those above with those below. For examination of the multiple levels of variables in the strategic supplier typology, we used analysis of variance (ANOVA). Factor analysis is used to assess the presence of latent constructs in the measured variables. An oblique rotation is used rather than an orthogonal rotation because we want to know the degree of relationship (correlation) between the two dimensions.

RESULTS

Descriptive statistics and correlation

To construct the two dimensions, we summed the variables for collaboration and technology using equal weights. A strong positive correlation ($r = 0.44$, $p = 0.000$) exists between the two dimensions. This strong correlation supports our description of Quadrant III: suppliers that develop collaborative relationships with their customers tend to be technologically sophisticated; suppliers that rely on normal market mechanisms to mediate their customer relationships tend to be less technologically sophisticated (Quadrant I).

Figure 1 gives the frequencies for all the firms on collaboration and technology scores. As the figure shows, 65 firms are in the PS quadrant (III) and 59 firms are in the CS quadrant (I). The remaining firms are distributed almost evenly between the other two quadrants. The Pearson chi-square tests show values that are significant at less than 0.001.

Collaboration factors

Next we factor analyzed the collaboration and technology variables to understand the underlying multivariate structure. The collaboration dimension reduced to five factors that accounted for 52 percent of the variance. These factors represent different aspects of both internal and external collaboration. Table 1 presents the factor loadings for this solution.

The first factor consists of ways in which firms communicate both internally between production and design personnel and externally with their customers on product and engineering design questions. This factor captures the use of cross-functional work teams both inside the firm and with customers. We call this factor *early supplier involvement in product development*, a process for developing new products which has received much attention lately (Cole, 1988; National Research Council, 1991; Fitzsimmons, Kouvelis, and Mallick, 1991).

We label the second factor *strategic vision*. This factor combines variables that describe how well a firm involves its employees in developing strategic plans and setting financial goals. The third factor describes how a firm relates to its primary customer and material supplier, i.e., it defines the attributes of collaboration '*upstream*' (further from the final customer) in the value chain. Factor three shows that if a supplier's customer requires certification, the customer tends to use long-term contracts and target pricing. The SMM supplier tends to require certification of its own material suppliers. We call this factor *customer/material supplier certification.*

The fourth factor has negative values on employee quality training and programs to develop supplier relationships. Firms that score high on this factor are unlikely to have high values on the first three factors. Factor four reinforces the importance of empowering employees through education/training in strategic management and quality practices, and developing collaborative supplier relationships. We call factor four *insufficient employee training*. The fifth and last factor indicates that firms develop distinct relationships with their equipment suppliers. These relationships differ significantly from the types of interactions with their customers and material suppliers. These differences arise because most firms purchase major equipment infrequently. We call this factor *equipment supplier certification.*

Technology factors

When we factor analyzed the technology variables, five new factors emerged (see Table 2). The first technology factor captures the importance of doing things right with your machines. It shows how a firm tracks machine downtime and idle time and how managers can use this information to improve machine operations. We label this factor *expert machine utilization*. The second technology factor identifies firms that design their own products with the use of computer-aided design (CAD) and computer-aided engineering (CAE) and then launches these products into production using complex planning/inventory control systems (MRP or similar). We interpret this factor to be an indicator of a firm's ability to do concurrent engineering and execute smooth ramp-ups of new products. We label this factor *quality function deployment.*

Factor three resembles factor one in that it establishes a measure for expert machine utilization. Factor three is confined to procedures for operating metal-working equipment, specifically computer numerically controlled (CNC) machine tools. We call this factor *process manufacturing know-how*. As in our collaboration factor results, factor four has high negative loadings for only a few variables. These negative values pertain to machine downtime and idle time. A high score here suggests that a firm is not expert in machine

Table 1. Factor loadings for collaboration variables

Measured variables	Factor loadings after oblique rotation[a]					
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	(h^2) Reliability
Q120 Customer—Long-term Contracts	0.10	0.18	**0.46**	−0.01	0.06	0.23
Q121 Customer—Target Pricing	0.04	0.10	**0.56**	−0.05	0.04	0.32
Q122 Customer—Certification	−0.04	0.15	**0.79**	−0.02	0.29	**0.66**
Q3–8 Vendor Certified by Customer	0.08	0.08	**0.51**	−0.15	0.10	0.27
Q6–1 Design—Production Involvement	**0.91**	0.27	0.09	−0.23	−0.08	**0.83**
Q6–3 Design—Customer Dialogue	**0.95**	0.30	0.04	−0.20	−0.07	**0.91**
Q6–4 Design—Customer Quality Stds.	**0.90**	0.31	0.09	−0.24	−0.04	**0.82**
Q6–6 New Prod.—Prototyping & Testing	**0.90**	0.29	0.11	−0.25	−0.04	**0.82**
Q1–3A Strategic Goals—Written	0.28	**0.77**	0.10	−0.33	−0.04	**0.61**
Q1–3B Strategic Goals—Used	0.17	**0.86**	0.11	−0.32	0.06	**0.77**
Q1–3C Strategic Goals—Comm. to Employees	0.15	**0.72**	0.20	−0.26	0.13	**0.55**
Q1–3D Strategic Goals—Modified	0.15	**0.68**	0.09	−0.12	−0.06	**0.48**
Q1–8 Financial Goals—Written & Comm.	0.25	**0.57**	0.12	−0.18	−0.04	0.34
Q1–9 Financial Goals—Available to Emps.	0.21	**0.43**	0.14	−0.32	−0.08	0.24
Q3–3 Seeks Customer Input on Products	0.20	0.09	−0.01	−0.17	−0.14	0.07
Q10–5 Quality System—Problem Prevention	0.11	0.16	−0.03	−0.31	0.02	0.11
Q10–10 Employee Quality Training	0.14	0.24	0.20	**−0.88**	0.05	**0.79**
Q126 Mat'l. Supp.—Single Source	0.12	−0.03	0.04	0.04	0.19	0.06
Q127 Material Supp.—Technical Assistance	−0.01	−0.01	0.28	−0.05	0.14	0.09
Q128 Material Supp.—Certification	−0.01	0.08	**0.58**	−0.13	0.09	0.35
Q129 Material Supp.—Long term Contracts	0.14	0.07	0.38	−0.02	0.21	0.18
Q132 Eqpt. Supp.—Single Source	−0.17	−0.06	−0.01	0.04	**0.42**	0.21
Q133 Eqpt. Supp.—Technical Assistance	−0.08	−0.07	0.23	−0.02	**0.77**	**0.62**
Q134 Eqpt. Supp.—Certification	0.10	0.16	0.32	−0.13	**0.50**	0.32
Q135 Eqpt. Supp.—Long-term Contracts	0.01	0.12	0.20	−0.01	**0.46**	0.23
Q5–9 Supplier Development Programs	0.21	0.29	0.28	**−0.52**	−0.06	0.34
Percent of Variance Accounted for	16.5	10.9	7.5	4.1	4.0	43.0

[a]Factors are shown in order of extraction: largest eigenvalue first. Loadings > 0.50 are highlighted in bold

utilization. We refer to factor four as *inexpert machine utilization.*

Finally, factor five provides information on the use of advanced manufacturing technology and procedures: programmable robotics, programmable controllers, and statistical process control. We label this factor *advanced process technology management*. Managers use these technologies to reduce variability in processes that already employ sound basic manufacturing practices. For this reason, we find the factor ordering to sequentially make good sense, i.e., good manufacturing practices precede advanced manufacturing technologies. Together these five factors account for more than 55 percent of the variance. Overall, looking at the strategic supplier typology matrix, we found the expected relationship between collaboration and technology. A firm with the administrative skills to enter partnerships was likely to have the know-how to manage advanced technology.

Table 2. Factor loadings for technology variables

Measured variables	Factor loadings after oblique rotation[a]					
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	(h^2) Reliability
Q6–0 Design Own Products	0.10	**0.44**	−0.11	−0.24	0.08	0.28
Q8–4A Machine Idle-time Records	**0.82**	0.15	0.36	**−0.50**	0.28	**0.83**
Q8–4B Machine Down-time Records	**0.94**	0.15	0.34	**−0.46**	0.34	**0.94**
Q8–4C Reasons for Machine Idle-time	**0.93**	0.11	**0.40**	−0.22	0.29	**0.97**
Q8–4D Reasons for Machine Down-time	**0.98**	0.11	0.32	−0.19	0.29	**1.00**
Q8–4E Analyze Reasons—Idle- and Down-time	**0.92**	0.16	0.35	−0.27	0.32	**0.84**
Q8–5A Tooling for Each Machine	0.36	−0.01	**0.53**	−0.11	0.23	0.34
Q8–5B Tools Stored as Sets	0.30	0.01	**0.56**	−0.09	0.11	**0.42**
Q8–5C Cutting Tools Properly Ground	0.20	−0.06	**0.79**	0.10	0.11	**0.65**
Q8–5D Use Quick Change or Preset Tooling	0.26	0.11	**0.65**	0.11	0.31	**0.47**
Q8–5E Use Cutting Tool Inserts	0.20	−0.05	**0.74**	0.21	0.15	**0.60**
Q8–6A Tech.: NC or CNC Machine Tools	0.27	0.17	**0.53**	0.28	**0.48**	**0.63**
Q8–6B Tech.: Programmable Robotics	0.38	0.27	0.13	−0.20	**0.67**	**0.53**
Q8–6C Tech.: Programmable Controllers	0.16	0.22	0.23	0.16	**0.72**	**0.54**
Q8–6D Tech.: Prod. Plan. & Inv. Cntl. Systems	0.09	**0.41**	0.03	0.16	0.36	0.35
Q8–6E Tech.: Automated Inspection	0.29	0.28	0.06	0.03	0.25	**0.63**
Q8–6F Tech.: Coordinated Measure Mach.	0.17	0.21	0.22	0.36	0.29	**0.46**
Q8–6G Tech.: CAD	0.12	**0.91**	0.07	0.22	0.30	**0.96**
Q8–6H Tech.: CAM	0.24	**0.40**	0.30	0.21	**0.50**	**0.46**
Q8–6I Tech.: CAE	0.11	**0.65**	0.12	0.12	**0.42**	**0.49**
Q8–6J Tech.: Statistical Process Control	0.28	0.29	0.12	0.12	**0.50**	**0.41**
Percent of Variance Accounted for	22.9	12.3	9.9	4.4	5.7	55.2

[a]Factors are shown in order of extraction: largest eigenvalue first. Loadings > 0.50 are highlighted in bold

Testing the hypotheses

We looked at supplier size based on both the number of employees and total sales. PSs have the largest number of employees (mean = 260), followed by collaborative specialists (mean = 150), technology specialists (mean = 44), and CSs (mean = 28). An ANOVA test produced an F ratio with a significance of 0.012, indicating that there are differences among the means for number of employees. Examination of the 95 percent confidence intervals for the means showed that all four quadrants were different from one another.

The picture is slightly different for total sales. Collaborative and technology specialists are not significantly different from one another. However, the mean sales for both PSs and CSs differ significantly from the mean sales for collaborative and technology specialists. These results are supported by an ANOVA test with a significance of 0.011, indicating differences among the means for sales. Based on these results, Hypothesis 1 is strongly supported for size of the firm expressed in number of employees, but must be qualified when using sales.

DISCUSSION AND CONCLUSION

Global competitiveness has altered the relationship between OEMs and their suppliers. One way that American OEMs have responded to Japanese lean manufacturing is by strategically outsourcing component parts and services. These actions have reshaped the way that suppliers compete with one another. This paper has extended the Clark and Fujimoto (1991) study on the automotive industry by looking at a variety of different industries; and the paper develops a typology rather than taxonomy. Our strategic supplier typology provides a clear picture of four supplier types. The most advanced and potentially most competitive are the problem-solvers. If these occur with the greatest frequency as in our sample, strategic outsourcing may be an important contributor to American manufacturing's renewed gains in productivity growth (Heye, 1993).

As predicted, firms in the PS quadrant (1) have the largest number of employees, (2) have the most firms and the highest percentage of export sales of any quadrant, (3) pay among the highest wages, and (4) have, along with CSs, the highest relative gross margins. We found this last finding surprising given our relational bias. It seems that commodity suppliers, like PSs, can earn quasi-rents. However, commodity suppliers do it 'the old-fashioned way,' by managing their input–output process more efficiently than their competitors. This suggests for strategy researchers that quasi-rents can be made either by focusing on a low-cost strategy or by mastering collaborative and technology skills. It seems that developing only one or the other of these two skills does not generate quasi- (relational-) rents.

In general, PSs achieve their competitive advantage by developing generic collaborative/technological know-how. This advantage comes from the vertical linkages that PSs establish with their multiple OEM customers (learning externalities). Yet, PSs themselves operate in a global economy since their OEMs scan the world market for suppliers. In this respect, global competition provides PSs with both opportunities and challenges. The opportunities are clear: more profitable business which requires organizational and individual skills which create competitive advantage.

This cross-sectional study identifies four basic supplier types and elaborates Clark and Fujimoto's supplier taxonomy for the auto industry and uses basic theoretical concepts to extend their work beyond a particular industry. However, while we have data on suppliers from various industries, the data set itself remains limited by geography and time. Future research should expand the data set across industries, geography, and time (economic cycles). For example, researchers may want to create a longitudinal data base and develop case studies to determine whether a transitional pattern exists for firms between different quadrants of the typology. Another avenue for future research is how OEMs might use the strategic supplier typology to subcontract different kinds of work: one type of supplier may be less costly or more suitable than another for a particular product or service. And finally, with the rapid acceleration in privatization and the use of outsourcing in the governmental or public sector, the development of a strategic supplier typology for this area would be a most appealing extension of the current research.

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