INNOVATION IN THE MULTINATIONAL FIRM WITH GLOBALLY DISPERSED R&D: TECHNOLOGICAL KNOWLEDGE UTILIZATION AND ACCUMULATION

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This paper employs evolutionary, resource-based, and knowledge-based perspectives to provide a framework for understanding technological knowledge sharing within the globally dispersed R&D function of the multinational firm. Elements from the three perspectives are inspected and drawn together. The constructs— knowledge, knowledge transaction, and performance—are articulated. Finally, two fundamental relationships are proposed: (1) kind of technological knowledge shared will impact the type of knowledge transaction undertaken and 2) type of knowledge transaction will impact R&D task performance.

INTRODUCTION

Despite increasing globalization, most academic investigations of dispersed R&D activities in the multinational firm have focused primarily on internationalization decisions rather than on the coordination or integration of these dispersed activities. Although a number of scholars suggest that a multinational firm's dispersed network of R&D activities should be managed as a globally integrated network, there are a limited number of studies that focus specifically on these issues. With regard to the actual integration of R&D activities at the operations level, we have little guidance.

With regard to the ability of the multinational firm to coordinate globally dispersed R&D operations as an integrated network, scholars have had opinions that differ. Fischer and Behrman (1979) conclude it is generally impossible to have a worldwide-integrated program of R&D. Although they concede it may be possible

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to do so on a regional basis (e.g., within Europe), it is otherwise problematic to maintain an adequate level of integration because of geographic distance. More recent literature suggests that integration of a multinational firm's globally distributed R&D may be desirable (from the perspective of competitive advantage) or even necessary in some industries (particularly where access to technological knowledge is a key determinant of success).

As noted, most studies to date have focused on the factors that determine why firms internationalize R&D activities. More recent studies have examined the organization of R&D activities from the perspective of specialized roles (centers of excellence (Ensign, Birkinshaw & Frost, 2000)). These roles are generally described in terms of a global or local product mandate. In an empirical study of innovation in the multinational firm, Bartlett and Ghoshal (1990) conclude that there are four generic kinds of innovation: center-for-global, local-for-local, locally leveraged, and globally linked. Other scholars (Chiesa, 1996; Nohria & Ghoshal, 1997) have reached similar conclusions. Most empirical studies, however, do not examine the extent to which dispersed activities are integrated at the operations level. It is suggested that this issue—the utilization and accumulation of technological knowledge—should be a concern of future research.

With the current emphasis on the importance of knowledge as a strategic asset, we would like to see studies that systematically examine technological knowledge sharing between R&D project groups at different locations within the firm (intergroup sharing of scientific information). Examining dispersed R&D activity within the multinational firm, the questions we would like to see answered are: 1) what is the nature and extent to which geographically and technologically dispersed R&D project groups share technological knowledge with other R&D project groups?; 2) what factors determine the utilization and accumulation of dispersed technological knowledge by R&D project groups?; and 3) does the utilization and accumulation of dispersed technological knowledge have an impact on the performance of an R&D task?

THEORETICAL PERSPECTIVES OF THE FIRM

An appropriate theoretical framework for such research would be one that provides an understanding of firm resources and capabilities. The proposed empirical exploration, therefore, would be based on three related and overlapping streams of literature: 1) evolutionary theory of the firm, 2) resource-based view of the firm, and 3) knowledge-based view of the firm. Each of these suggests that the firm is a collection of resources and capabilities that can be a source of sustainable competitive advantage.

Evolutionary and Resource-Based Views of the Firm

Scholars that focus on the theory of the firm (e.g., Nelson & Winter, 1982; Penrose, 1995; Penrose, 1959) have placed an emphasis on the dynamic aspects of firm growth. Changes in a firm's environment are accompanied by change and growth in the firm. In some industries, technological change has been almost relentless. The result is an increasingly competitive environment. Within the literature, how to achieve competitive advantage is a central issue. One approach to this issue—

based on industrial organization theory—is to focus on the industry (product/market) of a firm. Teece, Pisano, and Shuen (1997) describe this approach as the "competitive forces approach." Another approach—based on evolutionary and resource-based perspectives—is to focus on the utilization and accumulation of the distinctive resources and capabilities of a firm.

In evolutionary theory, the firm is conceived of as having a distinctive package of capabilities that are relatively narrow in scope. Information required for the functioning of the enterprise is stored in routines where much of the underlying knowledge is tacit (not known or articulable). As Nelson and Winter (1982) state, "routines are the skills of an organization." The firm has a limited range of technological capabilities based on its available routines and assets. There is no "shelf of technologies" external to the firm that is available to all industry participants. A firm's innovation capabilities are defined by what it has done in the past.

From an evolutionary perspective, what the firm can do is strongly influenced by its history. The concept of routines cuts across ideas on capabilities and strategic choice by treating them as "similar features of a firm" (Teece, 1984). A firm's distinctive technological capabilities and skills can be a source of competitive advantage (superior rents and performance). With regard to strategic choice, however, a firm's flexibility is constrained by the irreversible investments it has made in the past and by its range of available routines that are the result of past actions and activities. For the high technology firm competing globally, it is imperative that technologically valuable assets be utilized and accumulated internally, i.e., shared not squandered.

The resource-based view suggests that a firm's superior capabilities may be the source of improved rents (owing to lower costs, higher quality, or product performance). The focus is on the ownership advantages of scarce, firm-specific resources. Although earlier work described the significance of resources for firm growth (Learned, Christensen, Andrews, & Guth, 1965; Penrose, 1995 [1959]), the focus within strategic management is more recent. There is a growing body of literature that emphasizes the importance of firm-specific factors in explaining firm performance (Barney, 1991; Hall, 1992; Hall, 1993; Hansen & Wernerfelt, 1989; Mahoney & Pandian, 1992; Peteraf, 1993).

Although the general focus is on strategies for exploiting (utilizing) existing firm-specific assets, the resource-based perspective also suggests that firms must focus on developing (accumulating) new capabilities without regard to geographic limitations. If possession and utilization of unique technological resources and capabilities can be a source of economic rents then the acquisition or accumulation of such resources—wherever they may be found—is of equal or even greater importance. Teece, Pisano, and Shuen (1997) suggest that a dynamic capabilities approach is needed to understand skill acquisition, learning, and capability accumulation. The need for such an approach is that much more acute for a technology-driven multinational firm.

Within the resource-based perspective, resources are the "stocks" of available factors that are under the control of the firm. Resources are "converted into final products or services by using a wide range of other firm assets and bonding mechanisms such as technology" (Amit & Shoemaker, 1993: 35). Capabilities are described as a firm's capacity to deploy resources, usually in combination and using coordination and control processes, to achieve a desired end. Capabilities are based on

developing, carrying, and exchanging information through the firm's human capital. They are often developed in functional areas such as R&D. Itami (1987) describes these as information-based "invisible assets."

Taking the view that a firm is a bundle of heterogeneous resources and capabilities that can be utilized and accumulated over a period of time, the management of a firm's unique technological resources is of paramount importance for growth and profitability. This places technology managers in a position of leadership. They must focus on marshaling a set of complementary and specialized resources and capabilities for innovation. The literature suggests that these strategic assets—the ones that are scarce, durable, not easily traded, and difficult to imitate—can provide sustainable advantage and generate economic rents. To find such technology advancing resources may increasingly require global exploration.

Knowledge-Based View of the Firm

In the context of R&D, technological knowledge has traditionally been viewed as a critical resource. It has been central to the management of innovation and technology. More recently, an emphasis on knowledge and the management of knowledge has brought the knowledge-based view of the firm into the mainstream of strategic management thinking. Some of the primary contributors to this stream of literature are Grant (1995, 1996a, 1996b), Spender (1996), Hedlund (1994), Nonaka (1994), and Kogut and Zander (1992).

In traditional economic and organization theory, the focus is primarily on firm structure and behavior. Within strategic management, the resource-based view of the firm places a focus on how resources and capabilities impact performance and strategic choice. To the extent that the emphasis is on knowledge as the most important resource, the knowledge-based view of the firm is related to the resource-based view.

Grant (1996b) provides an introduction to the knowledge-based view of the firm. Although he suggests it is similar to the resource-based view, it goes beyond the traditional concerns of strategic choice and competitive advantage within the discipline of strategic management. It also addresses fundamental concerns in the theory of the firm. This includes an emphasis on: the nature of coordination within the firm and its implications for structure, the role of management and the allocation of decision-making rights, the determinants of firm boundaries, and the theory of innovation.

Rather than try to define knowledge, Grant (1996b) describes the characteristics of knowledge that have critical implications for management and the firm. These are: transferability of knowledge, capacity for aggregation of knowledge, appropriability of knowledge, knowledge specialization, and the knowledge requirements of production. Taken together, these characteristics suggest that firms exist to integrate the specialized knowledge possessed by a number of individuals because such integration cannot be performed efficiently across markets.

Starting with assumptions about the characteristics of knowledge and the requirements of production, the primary role of the firm is to integrate the specialized knowledge of individuals into goods and services. As Grant (1996b: 112) states, firms "can create conditions under which multiple individuals can integrate their

specialist knowledge." The primary responsibility of the technology manager is to establish the coordination necessary for the integration—the sharing or utilization and accumulation—of technological knowledge wherever it may be located.

Although Grant's focus on individual knowledge is consistent with Simon's (1991) observation that learning takes place within individuals, it differs from Spender's (1996) and Nonaka's (1991, 1994) focus on firm knowledge. But, as Grant (1996b) argues, such a focus can obscure: the organizing process through which firms access and utilize the knowledge of individual members, the mechanisms used for the creation of firm knowledge, and the importance of managers in this process.

Knowledge, Innovation, Technology, and R&D in the Multinational Firm

In describing a framework for analyzing knowledge in firms, Bonora and Revang (1993) indicate that many firms today operate in knowledge-intensive industries rather than capital-intensive or labor-intensive industries. This has resulted in a growing awareness of knowledge as a resource as well as the need for technological competence and innovation. These changes have contributed to an interest in the management of technological knowledge as a way of creating a sustainable competitive advantage. Although knowledge, technology, and innovation have traditionally been the focus in R&D, they are increasingly important in a globally competitive environment.

Conceptualization of Knowledge

The literature suggests that there are a number of ways to describe knowledge. These are generally referred to as the dimensions of knowledge. A number of these are related to the ease/difficulty of transferring knowledge. For example, Winter (1987) suggests four dimensions (each a continuum): tacit/articulable, not observable/observable, complex/simple, and element of system/independent. Zander and Kogut (1995) use five dimensions related to transfer: codifiability, teachability, complexity, system dependence, and product observability. They suggest that these measure different qualities of knowledge in the firm.

Knowledge is also described as procedural (related to process or performance of a task) and declarative (related to information, content, facts, or state). These are also called know-how and know-what. Finally, knowledge is described as individual and collective (Spender 1996) or individual, group, firm, and network (Kogut & Zander, 1992). However, as Nonaka (1994) indicates, knowledge is created by individuals. Firms cannot create knowledge without individuals. Therefore, firm knowledge—including its creation, utilization, and accumulation—must be understood as a social interaction process. A summary of these viewpoints and dimensions of knowledge is provided in Table 1.

In the context of the multinational firm, technological knowledge is viewed as both an output and an input. Technological knowledge is an output that results from the collective efforts of diverse specialists. High technology firms that produce sophisticated products—such as in the telecommunications industry—require specialists who

TABLE 1
Kinds of Knowledge

Procedural *describe a process*	Declarative *describe a state*	Blakeslee 1985
Procedural *required for performing a task*	Declarative *content, facts*	Fiske and Taylor 1991
Know-how	Information	Kogut and Zander 1992
Implicit, tacit	Explicit	Nelson and Winter 1982
Tacit	Communicable	North 1990
Tacit *implicit, associated with experience*	Explicit *know about*	Polanyi 1966
Know-how	Know-what	Ryle 1949
Implicit *automatic, collective*	Explicit *conscious, objectified*	Spender 1996
Know-how *accumulated practical skill or expertise that allows one to do something smoothly and efficiently*		von Hippel 1988
Tacit *not observable in use* *complex* *element of a system*	Articulable *observable in use* *simple* *independent*	Winter 1987

Level
- individual, group, organization, and network—Kogut and Zander 1992
- individual (Pareto rents) and social (Penrose rents)—Spender 1996

Dimensions
- routines and skills—Nelson and Winter 1982
- interactions between implicit and explicit in the formation of organizational knowledge—Nelson and Winter 1982; Nonaka and Takeuchi 1995
- codifiability, teachability, complexity, system dependence, and product observability—Zander and Kogut 1995

can turn information and experience into knowledge (Bonora & Revang, 1993). From a resource perspective, technological knowledge is also viewed as an input. As a strategic asset, it may even be the single most important input to the firm.

Although the importance of technological knowledge within the multinational firm is acknowledged, it is not well understood. What is required is an understanding of how scientific information that is produced in one location gets established, recognized, and how its development and utilization become organized, evaluated, and controlled in a wider context. Hedlund and Nonaka (1993) distinguish between: the storage of knowledge (as a stock), the transfer of knowledge (as a flow), and the transformation of knowledge (as interactions). Storage indicates that a stock of knowledge resides in a particular agent/person. Transmission refers to knowledge

that is communicated from one agent to another, including from one individual to another and from one group to another. Transformation indicates a process by which knowledge is "added, restructured, recontextualized, reinterpreted, etc., or through which new knowledge is generated" (Hedlund & Nonaka, 1993: 123).

From a resource-based perspective, firm-specific assets such as technological knowledge and skills are accumulated over time and reside, are even embedded, in a particular locale. As Dierickx and Cool (1989: 1506) suggest, "strategic asset stocks are accumulated by choosing appropriate time paths of flows over a period of time . . . while flows can be adjusted instantaneously, stocks cannot. It takes a consistent pattern of resource flows to accumulate a desired change in strategic asset stocks." Appropriate choices for the accumulation of technology creating resources and skills and appropriate time paths of relevant flows are needed to build asset stocks. The choice of optimal time paths of flows is reflected in a firm's current strategy. A firm's competitive position and profitability are determined by the level of its stocks and how it leverages them across geographic and product markets.

As Dierickx and Cool (1989) suggest, the sustainability of strategic or critical asset stocks is based on the degree to which they are non-tradable, nonimitable, and nonsubstitutable. Sustainability can be enhanced in the accumulation process by adding to already existing stocks (asset mass efficiencies) or by adding to complementary stocks (interconnectedness of stocks).

Studies that take a resource-based perspective describe the nature of firm-specific assets, skills, or capabilities in terms of source and kind, especially as they relate to technology. Technological knowledge can be intangible (e.g., skills, tacit knowledge) or tangible (e.g., patents, databases, etc.). Understanding that technological knowledge can be both used and accumulated is significant for the firm. Having the right kinds of firm-specific and strategic technological knowledge and in the right combinations may be of even greater significance.

Conceptualization of Innovation

In the context of R&D, a central focus is on innovation. Innovation is often viewed in terms of technology. Rogers (1983), in studying diffusion of innovations, describes five dimensions of innovation: relative advantage (profitability), communicability, observability, complexity, and compatibility. Compatibility indicates similarity to current experience, knowledge, and values. A number of these dimensions are similar to the dimensions used to describe knowledge.

The literature also describes the nature of innovation in terms of source and kind of innovation. Source can be either internal or external (von Hippel, 1988). With regard to kind, innovations are generally described as incremental (primarily adaptation of an existing product or process) or radical (the creation of something entirely new). Henderson and Clark (1990) suggest that some innovations can more accurately be described as architectural (changes in the way components are integrated into the system) or modular (changes in the components but no change in architecture).

As Henderson and Clark (1990) and Henderson and Cockburn (1994) indicate, some innovations are the result of the application of new technological knowledge. Other innovations result from the reconfiguring of existing technological knowledge

(architectural innovations). The multinational firm—owing to product and geographic spread—is particularly adept at combining knowledge from across technologies and locations. Kogut and Zander (1992: 391) suggest that the ability of the firm to "exploit its knowledge of the unexplored potential of technology" and "generate new combinations of existing knowledge" can be described as "combinative capabilities."

Innovation is also an evolutionary process. Van de Ven (1986) defines the innovation process as the development and implementation of new ideas by people who over time engage in transactions (activities or tasks) with others within an institutional context. The four elements in Van de Ven's definition are closely related to the four dimensions in Leonard-Barton's (1992) conceptual development of core capabilities: skills and knowledge base, technical system, managerial system, and values and norms. Again, the multinational firm often has the necessary characteristics—information management technology, coordination and control mechanisms, and a common corporate culture—to fruitfully combine technology building capabilities.

Van de Ven's (1986) definition of the innovation process is broad enough that it can include technological innovations (new technologies, products, and services) and firm innovations (new procedures, policies, and organization forms). In his view, technological and firm changes both occur (co-evolve) in the development of an innovation. Understanding the relationship between the two is important for the management of innovation.

Conceptualization of Technology

When technology is defined, it is often described as knowledge or combined information. As Zander and Kogut (1995) suggest, technology is often: firm-specific, differentiated knowledge about specific applications which is largely cumulative within firms; arrived at through experience—for example, a multiunit firm can develop a set of rules or higher order organizing principles by which new capabilities are created, improved, and transferred; and based on capabilities which are idiosyncratic to individuals and small groups.

Transformations that require complex processes to occur are the essence of technological innovation (technological knowledge creation). As Hedlund and Nonaka (1993: 124) indicate, "Creation involves the introduction of new kinds of data, reinterpretation of old knowledge, recombination of data, and new holistic conception of tangible outputs." They propose a model, which includes knowledge categories (tacit and articulated) and transformation processes that occur at the individual, group, firm, and interfirm levels. The multinational firm—both itself structurally organized as a network and participating in external networks—is particularly suited for conducting such transformations.

Teece, Pisano, and Shuen (1997) suggest that complementary or co-specialized assets—where value is enhanced by a different class of innovative activities—will direct a firm's resources on a particular course. In an empirical study of oil companies, Teece (1980) found that firm patterns of R&D and operations were consistent with economies of scope due to complementary technological knowledge. Helfat (1997) also found empirical evidence for a relationship between complementary

technological knowledge and R&D in alternative products. This points to an inherent strength of the multiproduct, geographically dispersed firm.

In describing the fundamental characteristics of technological advance, Cantwell (1992) suggests that innovation competence results from the nature of technology and the way in which it develops, i.e., is utilized and accumulated. He indicates that the central ideas on this issue were first articulated by Nelson and Winter (1982). Cantwell's basic proposition is that technology is partially tacit and context-specific (based on the firm and location in which it was created or adapted), to which he adds six other related propositions. Technological innovation is a cumulative process. Innovation proceeds incrementally. Technology is differentiated between firms and locations. Technological change is partially irreversible. The specific path of innovation is constrained by a system of technological interrelatedness between firms and types of activity. The direction taken by the search processes of firms and the rate of innovation they achieve is governed by the underlying growth of technological opportunities.

Internal Technological Knowledge Building in R&D

In describing the two faces of R&D, Cohen and Levinthal (1989: 569) indicate that R&D not only generates new information but also "enhances the firm's ability to assimilate and exploit existing information." Firms invest in their own R&D not just for product innovations but so they can use information that is available inside or outside the firm. They describe the ability to identify, assimilate, and exploit technological knowledge as absorptive capacity.

In assessing R&D in the firm, Cohen and Levinthal (1989) conclude: the long-run cost of learning is substantial; this cost is related to the development of the firm's stock of prior technological knowledge (absorptive capacity); and the primary benefit of R&D is its contribution to this technological knowledge base. As Dierickx and Cool (1989) suggest, the accumulation or possession of asset stocks does not prevent their erosion over time. Accumulation requires continuing efforts and allocation of resources.

Knowledge Flows in the Multinational Firm

In a study of differences in the strategic contexts of subsidiaries, Gupta and Govindarajan (1991) describe the multinational firm as a network of transactions. These transactions consist of capital flows, product flows, and knowledge flows. In general, most research has focused on financial flows and product flows, primarily because data are more readily available to measure such intrafirm trade. Gupta and Govindarajan (1991) focus specifically on knowledge flows. Their study discusses knowledge flows (between units in different physical locations) based on two dimensions—"magnitude" ("volume and criticality") and "directionality" ("receivers or providers") of transactions. Although their work (including Gupta & Govindarajan, 1993) was designed to examine the relationship between knowledge flows and management coordination and control factors, it serves as an initial step in exploring knowledge transactions.

TECHNOLOGICAL KNOWLEDGE INTEGRATION, TECHNOLOGICAL KNOWLEDGE STRUCTURE, AND R&D TASK PERFORMANCE

A number of recent studies emphasize the importance of technological knowledge in the firm. Clearly, the emphasis is on how technology can be utilized and accumulated to achieve competitive advantage. These studies underscore the importance of understanding the relationship between technological knowledge creation and firm R&D activities. The focus is on interactions—the integration and sharing of technological knowledge—that build firm capabilities.

Conceptualization of Technological Knowledge Integration

The primary emphasis in looking at firm learning is on the role of the firm in the acquisition, processing, storage, and application of information. Nonaka (1994) proposes a theory of knowledge creation that focuses on the dynamic interaction between tacit and explicit knowledge—two dimensions of knowledge transfer. Spender (1996: 59) describes a "system of knowledge production and application." That is, firms engage in knowledge application as well as knowledge creation. Demsetz (1991) too describes the distinction between these two processes. Efficiency in creation or acquisition of knowledge requires specialization, i.e., individuals who specialize in specific areas of knowledge. The application of technological knowledge to produce goods and services requires integration—a bringing together of specialized technological knowledge.

A review of literature indicates that there are a growing number of studies on issues related to the integration—the sharing or utilization and accumulation—of technological knowledge. Most of this research has focused on technological knowledge integration in the context of new product development (Clark & Fujimoto, 1991; Nonaka, 1994; Wheelwright & Clark, 1992). Extending this literature, Grant (1996b) describes a theory of firm capability that results from the ability of the firm to integrate the specialized knowledge of individuals. It is based on assumptions related to the characteristics of knowledge and how knowledge is deployed. These assumptions are: knowledge is the principal productive resource of the firm; of the two main types of knowledge—explicit and tacit—tacit is especially important due to limited transferability; tacit knowledge is acquired by and stored within individuals in highly specialized form; and production requires a wide range of knowledge (Grant, 1996b: 385).

From these assumptions, Grant (1996b) develops propositions related to the nature of firm capabilities and their linkage to organizing structure. First, the fundamental role of the firm is the integration of individuals' specialist knowledge (creation of firm capability). Second, the capabilities of the firm are "hierarchically structured according to the scope of knowledge which they integrate. Effectiveness in creating and managing broad-scope capabilities requires correspondence between the scope of knowledge and the structures needed for managing such integration" (Grant, 1996b: 385). A third proposition is related to integration mechanisms. The two primary mechanisms suggested are direction and routine. In the case of direction, the need for direction increases with complexity of the activity, the number of locations in which the activity is performed, and the stringency of performance

specifications. In the case of routine, the advantage is that it economizes on communication and permits flexible responses to changing circumstances. Across locations—despite a variety of national cultures and institutions—a multinational firm's policies, procedures, and even its informal norms regulate and direct behavior.

Conceptualization of Technological Knowledge Structure

Iansiti (1995) approaches the subject of integration of technological knowledge by using the context of R&D. Taking the perspective that a new product is the result (combination) of new and existing technological knowledge, he describes a technology integration process that consists of a "set of knowledge-building activities through which novel concepts are explored, evaluated, and refined to provide the foundation for product development" (Iansiti, 1995: 521–522). He suggests it is an integrative process because managing the relationship between new and old technological knowledge requires the combination of different sources of scientific information. This means it is a system-focused process based on a foundation of existing (system-wide) technological knowledge.

Approaching innovation from this perspective places the focus on a broad set of issues that are not linked to the physical architecture of the product. Henderson and Clark (1990), for example, focus on the physical architecture of the product by emphasizing the linkage between specialized technological knowledge and component design. Iansiti (1995) maintains that products should not be thought of simply as an aggregation of components but as the integrated outcome of a complex system of technological knowledge.

Iansiti's (1995) research suggests that R&D tasks have a critical "architectural" impact on the product's technological knowledge base, with relationships shifting between new and existing disciplinary expertise. Over time, a firm's technological knowledge base and its information processing capabilities adapt to the structure of its R&D activities. Iansiti (1995) argues that the evolution of this technological knowledge base is determined by how it is managed during the process of technology integration. The focus of management should be on the structure of the entire technological knowledge base that is—or that will potentially be—required.

Although the primary focus of Iansiti's study is on pre-development routines (occurring in the R&D task conceptualization and specification stage) and their impact on performance, his study suggests that the structure of technological knowledge can and should be managed proactively. Even when R&D tasks involve only minimal changes to a previous generation of products or processes, these substitutions can completely restructure the technological knowledge base necessary for production. R&D tasks have the potential to alter: 1) the structure of technological knowledge and how it is distributed, 2) the specialization of technological knowledge, and 3) decision making.

R&D Task Performance

With regard to the impact of technological knowledge integration and technological knowledge structure on R&D task performance, a review of the literature indicates that most studies focus only on the output of technological knowledge—the

product developed. In general, there are a limited number of studies that focus specifically on R&D task performance.

Two recent studies that focus on the design and management of R&D task conclude that a comprehensive conceptualization of the product at the beginning of the R&D task can impact its performance. Dougherty (1992: 87) reports that successful innovators devoted time in the beginning of an R&D task to "construct a full definition of the product concept. . . . The failed innovators worked with an incomplete or partial product definition." Even though the initial conceptualization may seem unclear, "it frames the feasible set of product attributes. . . . Over time, innovators clarify the boundaries of the set by filling in the details of the product concept and operationalizing it into a physical configuration of attributes" (Dougherty, 1992: 87–88).

The empirical study of Iansiti (1995) extends these ideas. In addition to providing insight on technological knowledge integration and technological knowledge structure (reviewed in the previous sections), the primary focus was on investigating the impact of technology integration routines on the performance of R&D activities in an environment characterized by discontinuous change. R&D task performance was measured by development lead-time, R&D productivity, and technical product improvement (using company records and interview data).

Based on his research, Iansiti (1995: 521) concludes that, "differences in performance are correlated with skills and routines aimed at technology integration." He suggests that the technology integration process must include a specific set of technological knowledge building activities during the early stages of a development task. It must include bringing together the right individuals with direct experience in related product introduction efforts. As Iansiti (1995: 522) states, the process "frames the project, providing a critical road map to guide design and development activities. The activities . . . set the direction for the evolution of knowledge . . . and provide a critical opportunity for the management of technological evolution."

THEORETICAL PERSPECTIVES AND TECHNOLOGICAL KNOWLEDGE SHARING

In this section, ideas related to technological knowledge and the sharing (both utilization and accumulation) of technological knowledge are synthesized. This will be done using the three streams of literature related to the evolutionary, resource-based, and knowledge-based perspectives.

Firm Routines as Procedural Knowledge (Know-How)

From an evolutionary perspective, a firm's technological knowledge is stored in its routines and operating procedures. To Nelson and Winter (1982), firm routines are the skills of the firm; they are the "regular and predictable behavioral patterns" that can be distinguished from other behavior by being "persistent, heritable and selectable." Winter (1990: 276) describes a routine as a "pattern of activity," a "process," and "organizational performance."

An important distinction is made between firm and individual technological knowledge. Nelson and Winter (1982) indicate that firm routines embody the firm's

capabilities or skills. However, firm technological knowledge is more than the aggregated technological knowledge of individual members. The increased value based on the sharing of experiences is the distinguishing factor between individual and firm technological knowledge. Over time, firm technological knowledge results from a process of interactions among people who transfer, share, contribute, and interpret scientific information or technological knowledge among themselves during R&D activity.

Intrafirm technological knowledge sharing (sharing between subunits) describes learning that takes place when people in one R&D project group learn by acquiring technological knowledge from other R&D project groups within the firm. But as Nelson and Winter (1982: 118) indicate, the interunit replication of routines (the internal replication problem) is a "noisy" process; replication is a "costly, time-consuming process of copying an existing pattern of productive activity." Szulanski (1996) describes the problem of transfer as being one of "internal stickiness."

In this paper attention is drawn to the importance of focusing on the kind of technological knowledge shared between R&D project groups. Based on an understanding of evolutionary theory, technological knowledge in routines is primarily procedural technological knowledge (situated performance). Routines may embody specific scientific information about how to perform certain R&D tasks as well as the overarching rules of behavior to carry them out.

Firm Assets as Declarative Technological Knowledge (Know-What)

From a resource-based view, technological knowledge is an asset that depends on the specialized abilities of individuals and groups. When technological knowledge assets are tacit, complex, and elements of a larger system, they are less imitable. Such assets—those related to a firm's ability to perform skills in an intelligent way (Winter, 1987)—can be a source of sustainable advantage. For firms that compete on intellectual assets, technological knowledge sharing between different technologies and physical locations in a multiunit, multinational firm is of great importance. Teece and Pisano (1994) suggest that cross unit coordination is essential because many of these competences span subunits. The utilization and accumulation of technological knowledge, therefore, requires intrafirm arrangements or mechanisms that can facilitate interunit sharing of scientific information.

Taking a resource-based perspective, asset stocks of technological knowledge can generally be described as declarative technological knowledge. Specialization by individuals and groups (especially specialization within science or technology) is the essence of "know-what" knowledge.

The Firm as an Integrator of Technological Knowledge

From a knowledge-based perspective, a primary role of the firm is to provide for the integration of specialized knowledge (Demsetz, 1991; Grant & Baden-Fuller, 1995). Based on the premise that the firm is more efficient than markets in the transfer and integration of scientific information, understanding how technological knowledge sharing occurs within the R&D function of a multinational firm is of substantial importance.

Grant and Baden-Fuller (1995: 18) suggest that the firm's efficiency in integrating

knowledge is based on the extent to which it is able to "access and utilize the specialized knowledge which is stored within its individual members." This is determined by two factors: the efficiency of integration mechanisms, and the extent of knowledge capacity utilization. Presently there exists software packages (both off-the-shelf and customized) to assist R&D personnel in sharing scientific information across technological and geographic boundaries within the firm. Multinational firms have been struggling with the leveraging of technological knowledge for some time. The Swedish multinational communications firm Ericsson has employee rotation policies to ensure that engineers and scientists have exposure to a variety of technologies and physical locations. Ericsson consciously integrates R&D activity among different sites; the division of labor for any individual R&D task may force the sharing of technological knowledge across boundaries of: business/product line, nation/culture, and technology. Finally, as Grant and Baden-Fuller (1995: 18) state, "If efficiency requires that knowledge is acquired and stored in specialized form, but its application requires bringing together many types of knowledge, then some mechanism must exist for the integration of knowledge." To this insight, it should be added that mechanisms to facilitate utilization and accumulation of technological knowledge are still evolving and will to continue to develop alongside the march of technological progress.

IMPLICATIONS FOR FURTHER STUDY AND PROPOSITIONS

The ideas presented in the previous sections—drawing on evolutionary, resource-based, and knowledge-based perspectives—provide a framework for understanding the concept of technological knowledge sharing within the globally dispersed R&D activity of the multinational firm. The extensive literature on resources is useful in understanding that technological knowledge sharing is an important way of building unique firm capabilities for innovation—the driver of firm growth. Amit and Schoemaker's (1993) conceptualization of resources in terms of "stocks" and "flows" is particularly instructive. It is also helpful in recognizing that scientific information may be both utilized and accumulated. These ideas help to focus attention on technological knowledge sharing as a process that can be managed.

In this paper we have described technological knowledge sharing as a knowledge transaction. The characterization of knowledge flow as a transaction (or series of repeated transactions) is beneficial. Technological knowledge transactions may be described by type based on: number and duration of interactions, importance of interactions, level at which activity occurs (e.g., R&D project group manager or employees), mechanisms (formal or informal), and stage in the R&D task.

The recent knowledge-based literature places a focus directly on the need to understand technological knowledge. The emphasis is on understanding that there are different kinds of knowledge. These have also been described as the dimensions of knowledge. The traditional emphasis has been on describing them from an epistemological perspective: tacit (difficult to transfer, not observable in use, and complex) or articulable (communicable, observable in use, and simple). Most research studies to date have used this concept of knowledge, primarily because the focus has been on the issue of the transferability of knowledge.

We argue that using this traditional view of knowledge would limit an understand-

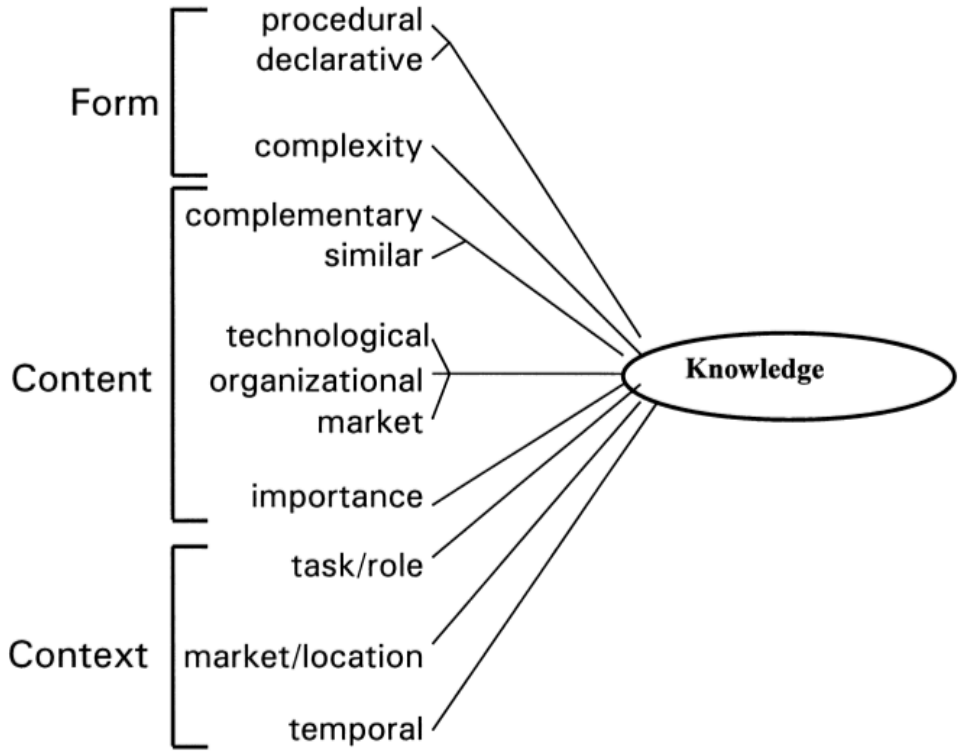

FIGURE 1
Characterization of Knowledge

ing of knowledge sharing in the context of R&D. In our view knowledge should be defined in terms of content and include consideration of its context in the firm. In future study the focus should be on knowledge dimensions that are specifically relevant to R&D operations. We describe knowledge as being: complementary or similar (relative to existing knowledge base) and procedural or declarative (in terms of its application) (Figure 1).

A central argument is that the nature (characteristics or attributes of the scientific discipline/field) of technological knowledge shared determines the type of knowledge transaction that takes place. We suggest that the major determinant of the type of knowledge transaction is the kind of scientific information shared. This is stated in the first proposition.[1]

P1: Kind of technological knowledge shared will impact the type of knowledge transaction.

The second proposition is directly related to this proposition. If different kinds of technological knowledge result in different types of knowledge transactions then we can expect differences in R&D task performance by type of knowledge transaction. This is stated in the second proposition.

P2: Type of knowledge transaction will impact R&D task performance.

R&D task performance could be examined by: emphasis on utilization and/or

[1] Certainly, refinements could be made to proposition 1 as the influence of other dimensions of technological knowledge are explored. Additional factors such as economic, organizational, and sociological conditions could also be incorporated into explaining a knowledge transaction.

TABLE 2
Summary of Knowledge Sharing

Kind of technological knowledge
Relative to knowledge base:
- complementary ("some distance from" existing knowledge base) or similar ("near" existing knowledge base)

In terms of its application:
- procedural (know-how) application of technological/managerial project experience or declarative (know-what) application of specific technical expertise

Type of knowledge transaction
- number and duration of interactions
- importance of interactions
- decision initiative (R&D general manager, project group manager, or project group employee)
- mechanisms (formal or informal)
- stage in project (when it occurs)

R&D task performance
- utilization (current use) and accumulation (future use)
- achievement of expected objectives
  - economic
  - technological
  - strategic/organizational

accumulation of technological knowledge, importance of scientific information, and the achievement of expected outcomes (product improvement, invention, patents, etc.). A more complete description of the measures for kind of technological knowledge, type of knowledge transaction, and R&D task performance would be context specific. An overview is provided in Table 2.

As described in the introduction to this paper, future empirical studies should examine technological knowledge sharing between R&D project groups in different locations and technologies within the multinational firm (intergroup sharing of scientific information). Based on a review of the literature, no studies were located that focus specifically on this issue. This paper, therefore, may be thought of as the groundwork for further exploration of: 1) the nature and degree to which geographically and technologically dispersed R&D project groups share technological knowledge with other R&D project groups, 2) the factors that impact the utilization and accumulation of dispersed technological knowledge by R&D project groups, and 3) the impact that technological knowledge sharing among globally dispersed R&D project groups has on R&D task performance.

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