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KNOWLEDGE OF THE FIRM, COMBINATIVE CAPABILITIES, AND THE REPLICATION OF TECHNOLOGY*

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How should we understand why firms exist? A prevailing view has been that they serve to keep in check the transaction costs arising from the self-interested motivations of individuals. We develop in this article the argument that what firms do better than markets is the sharing and transfer of the knowledge of individuals and groups within an organization. This knowledge consists of information (e.g., who knows what) and of know-how (e.g., how to organize a research team). What is central to our argument is that knowledge is held by individuals, but is also expressed in regularities by which members cooperate in a social community (i.e., group, organization, or network). If knowledge is only held at the individual level, then firms could change simply by employee turnover. Because we know that hiring new workers is not equivalent to changing the skills of a firm, an analysis of what firms can do must understand knowledge as embedded in the organizing principles by which people cooperate within organizations.

Based on this discussion, a paradox is identified: efforts by a firm to grow by the replication of its technology enhances the potential for imitation. By considering how firms can deter imitation by innovation, we develop a more dynamic view of how firms create new knowledge. We build up this dynamic perspective by suggesting that firms learn new skills by recombining their current capabilities. Because new ways of cooperating cannot be easily acquired, growth occurs by building on the social relationships that currently exist in a firm. What a firm has done before tends to predict what it can do in the future. In this sense, the cumulative knowledge of the firm provides options to expand in new but uncertain markets in the future.

We discuss at length the example of the make/buy decision and propose several testable hypotheses regarding the boundaries of the firm, without appealing to the notion of "opportunism."

(ORGANIZATIONAL KNOWLEDGE; TECHNOLOGY TRANSFER; IMITATION; CAPABILITIES; LEARNING)

A fundamental puzzle, as first stated by Michael Polanyi (1966), is that individuals appear to know more than they can explain. That knowledge can be tacit has broad implications for understanding the difficulty of imitating and diffusing individual skills, a problem lying at the heart of artificial intelligence to the competitive analysis of firms. Though the idea of tacit knowledge has been widely evoked but rarely defined—as if the lack of definition is itself evidence of the concept, it represents a dramatically different vantage point by which to analyze the capabilities and boundaries of firms.

This article seeks to lay out an organizational foundation to a theory of the firm. To rephrase Polanyi's puzzle of tacit knowledge, organizations know more than what their contracts can say. The analysis of what organizations are should be grounded in the understanding of what they know how to do.

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It is curious that the considerable attention given to how organizations learn has obscured the implication that organizations "know" something. In fact, the knowledge of the firm, as opposed to learning, is relatively observable; operating rules, manufacturing technologies, and customer data banks are tangible representations of this knowledge. But the danger of this simple characterization is that everything that describes a firm becomes an aspect of its knowledge. While this is definitionally true, the theoretical challenge is to understand the knowledge base of a firm as leading to a set of capabilities that enhance the chances for growth and survival.

In our view, the central competitive dimension of what firms know how to do is to create and transfer knowledge efficiently within an organizational context. The following article seeks to describe these capabilities by analyzing the contention put forth by Winter (1987) that technology transfer and imitation are blades of the same scissor. The commonality is that technology is often costly to replicate, whether the replication is desired by the firm or occurs by imitation and unwanted diffusion. Though the terminology may differ, the underlying phenomena impacting the costs of technology transfer and imitation share similarities, regardless whether the replication occurs within the firm, by contract, or among competitors.

That similar factors may determine both the costs of imitation and technology transfer presents an interesting dilemma to the firm. In the efforts to speed the replication of current and new knowledge, there arises a fundamental paradox that the codification and simplification of knowledge also induces the likelihood of imitation. Technology transfer is a desired strategy in the replication and growth of the firm (whether in size or profits); imitation is a principal constraint.

Our view differs radically from that of the firm as a bundle of contracts that serves to allocate efficiently property rights. In contrast to the contract approach to understanding organizations, the assumption of the selfish motives of individuals resulting in shirking or dishonesty is not a necessary premise in our argument. Rather, we suggest that organizations are social communities in which individual and social expertise is transformed into economically useful products and services by the application of a set of higher-order organizing principles. Firms exist because they provide a social community of voluntaristic action structured by organizing principles that are not reduceable to individuals.

We categorize organizational knowledge into information and know-how based, a distinction that corresponds closely to that used in artificial intelligence of declarative and procedural knowledge. To move beyond a simple classification, these types of knowledge are argued to carry competitive implications through their facility to be easily replicated within an organization but difficult to imitate by other firms. Following the suggestions of Rogers (1983) and Winter (1987), the characteristics of both types of knowledge are analyzed along the dimensions of codifiability and complexity. By examining first personal expertise and then social knowledge, the capabilities of the firm in general are argued to rest in the organizing principles by which relationships among individuals, within and between groups, and among organizations are structured.

But organizations serve as more than mechanisms by which social knowledge is transferred, but also by which new knowledge, or learning, is created. The theoretical problem is that if the knowledge of the firm is argued to be competitively consequential, learning cannot be characterized as independent of the current capabilities. To explore this dynamic aspect, we introduce the concept of a **combinative capability** to synthesize and apply current and acquired knowledge. This concept is, then, explored in the context of a competitive environment. By this discussion, we ground such concepts as localized learning to path dependence by developing a micro-behavioral foundation of social knowledge, while also stipulating the effects of the degree of environmental selection on the evolution of this knowledge.

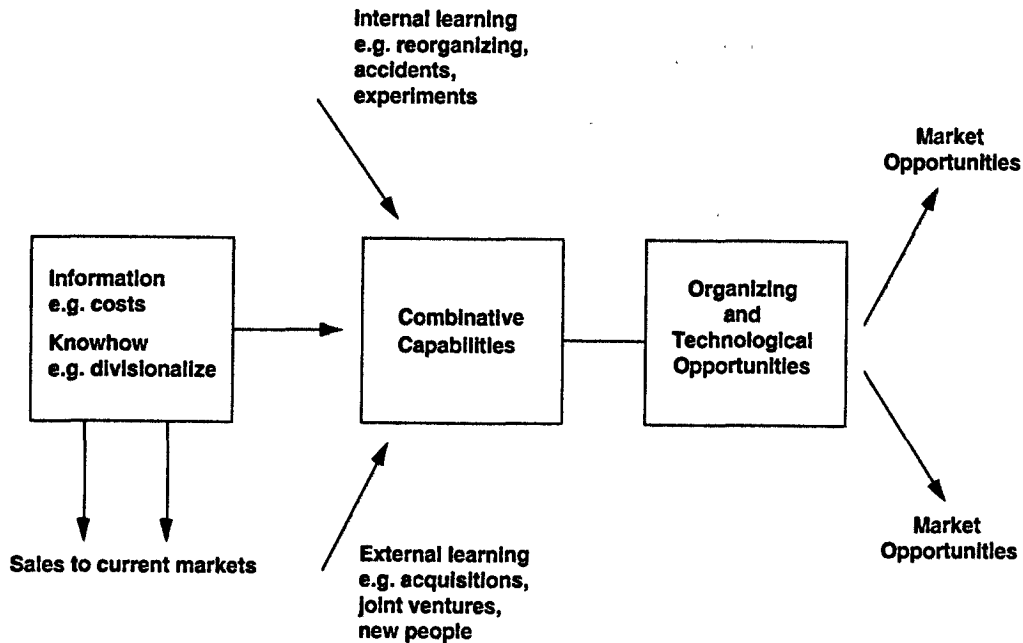


FIGURE 1. Growth of Knowledge of the Firm.

To ground the abstraction of the argument in an example, we reexamine the empirical findings on the make-buy decision of firms. The importance of the ability to generate new knowledge suggests a different view on the “boundaries” of the firm, that is, what a firm makes and what it buys. Firms invest in those assets that correspond to a combination of current capabilities and expectations regarding future opportunities. Or, in other words, the knowledge of a firm can be considered as owning a portfolio of options, or platforms, on future developments.¹

Figure 1 provides a roadmap to our argument. We begin by analyzing the knowledge of the firm by distinguishing between information regarding prices and the know-how, say, to divisionalize. This static portrait is the basis by which we explore how knowledge may be recombined through internal and external learning. An important limitation to the capability of developing new skills is the opportunity (or potential) in the organizing principles and technologies for further exploitation. Eventually, there are decreasing returns to a given technology or method of organizing, and there, consequently, results in an incentive to build new, but related skills. These investments in new ways of doing things, we suggest, serve as platforms on future and uncertain market opportunities.

It is important to underline the presumption that the knowledge of the firm must be understood as socially constructed, or, more simply stated, as resting in the organizing of human resources. The issue of the organizing principles underlying the creation, replication, and imitation of technology opens a window on understanding the capabilities of the firm as a set of “inert” resources that are difficult to imitate and redeploy.² It is the persistence in the organizing of social relationships in which knowledge is embedded that is the focus of inquiry developed in this article.

¹This notion of a platform is investigated in Kogut (1991) and Kogut and Kim (1991).

²See Lippman and Rumelt (1982), Wernerfelt (1984), Rumelt (1984), Barney (1986), and Kogut (1987), as well as the publications that appeared while this article was under review by Dierickx and Cool (1989) and Prahalad and Hamel (1990).

Information and Know-How

There have been many suggestions as to how the knowledge of the firm might be categorized. Nelson (1982), for example, separates *techno* from *logy*, the former belonging to a firm, the latter to the public arena. A more common distinction is between research and development, or that between process and product.

For our purposes, we distinguish between two categories of knowledge as information and know-how.³ By information, we mean knowledge which can be transmitted without loss of integrity once the syntactical rules required for deciphering it are known. Information includes facts, axiomatic propositions, and symbols. Nelson's idea of *logy* is, in fact, a recognition that within scientific communities, there exists a social agreement regarding the factual evidence by which to communicate the reliability of scientific findings. Similarly, public firms are required to report data to shareholders in a common format so as to facilitate analysis and appraisal. For the objective of public dissemination, information is standardized and released in order to be understood at minimal cost to those with the requisite training.

Of course, information is often proprietary. Firms maintain, as a rule, two sets of accounting data, one for external use, the other to aid managerial decisions and evaluation. Data can also be of competitive value. An obvious example is the value of information to traders of financial securities, but a more prosaic example is the data acquired by grocery stores on consumer expenditures.

Know-how is a frequently used, but rarely defined term. Von Hippel offers the definition that "know-how is the accumulated practical skill or expertise that allows one to do something smoothly and efficiently" (von Hippel 1988). The pivotal word in this definition is "accumulated," which implies that know-how must be learned and acquired.

Knowledge as information implies knowing *what* something means. Know-how is, as the compound words state, a description of knowing *how* to do something. In economics, this distinction is, implicitly, preserved in the often made distinction between exchange and production economies, where the former consists of only traders responding to prices, and the latter to how inputs are transformed into outputs. To use a current example, the problems of the adoption economy in Eastern Europe consist not only of just finding the right prices, but also learning how to organize a market and a firm efficiently.

Though this distinction between information and know-how appears to be a fundamental element in the analysis of organizational knowledge, most efforts in this direction have tended, following March and Simon (1958) and Cyert and March (1963), to investigate the notion of routines in the context of organizational learning. Yet, this vantage point for the investigation of firm knowledge is ill-chosen. Learning has little significance in the absence of a theory of organizational knowledge.

A routine is in itself an insightful but incomplete characterization of knowledge. Because of the broad coverage of the term routine, an appeal is often made to the analogy of a blueprint, an analogy favored by a number of authors.⁴ But a blueprint favors much more a description of information than know-how. Knowing how to do something is much like a recipe; there is no substantive content in any of the steps, except for their capacity to produce a desired end.⁵ The information is contained in

³Steve Kimbrough has pointed out in conversation that the terms are similar to Bertrand Russell's distinction between know-that and know-how.

⁴See Nelson and Winter (1982); Hannan and Freeman (1977); March and Simon (1958).

⁵In light of the wide appeal genetics has for organizational analogies, it is of interest to refer to Dawkin's (1987) discussion of genes as recipes (and the phenotype as a blueprint). See also Simon (1962).

the original listing of ingredients, but the know-how is only imperfectly represented in the description.

It is revealing that this distinction between information and know-how as blueprints and recipes is similar to that made between declarative and procedural knowledge used in computer science. Declarative knowledge consists of a statement that provides a state description, such as the information that inventory is equal to a 100 books. Procedural knowledge consists of statements that describe a process, such as a method by which inventory is minimized. This distinction is robust to other phenomena than software, even to a furniture set where the inventory of parts is first described and then the recipe of assembly laid out.

Know-how, like procedural knowledge, is a description of what defines current practice inside a firm. These practices may consist of how to organize factories, set transfer prices, or establish divisional and functional lines of authority and accountability. The knowledge displayed in an organizational chart, as in any blueprint, is limited to providing information on personnel and formal authority. The know-how is the understanding of how to organize a firm along these formal (and informal) lines. It is in the regularity of the structuring of work and of the interactions of employees conforming to explicit or implicit recipes that one finds the content of the firm's know-how.

The Inertness of Knowledge

Firms differ in their information and know-how and these differences, when they are economically interesting, have persisting effects on relative performance. Thus, a central characteristic to be explained is the persisting difference in capabilities, that is, the difficulty in their transfer and imitation. The persistence of differentials in firm performance lies in the joint problem of the difficulty of transferring and imitating knowledge.

There is a need, therefore, to go beyond the classification of information and know-how and consider why knowledge is not easily transmitted and replicated. The transferability and imitability of a firm's knowledge, whether it is in the form of information or know-how, are influenced by several characteristics (Kogut and Zander 1990). Rogers (1983) and Winter (1987) have proposed that knowledge can be analyzed along a number of dimensions.

Consider the two dimensions of codifiability and complexity. Codifiability refers to the ability of the firm to structure knowledge into a set of identifiable rules and relationships that can be easily communicated. Coded knowledge is alienable from the individual who wrote the code. Not all kinds of knowledge are amenable to codification. Drafting a recipe for the manufacturing of a musical instrument is unlikely to capture the requisite skills of a craftsman.

Nor is this limitation only applicable to know-how. It is not always possible to identify the relevant information which operates as the data to an actor or set of actions. There may be no 'theory' (in the sense used above) by which to identify the relevant information, such as drawing the blueprint. This argument bears similarities to the artificial intelligence debate on the obstacles to formalizing noncodified "background knowledge" to scientific theories (Dreyfus and Dreyfus 1988). Codifiability is a question of the degree that there exists an implied theory by which to identify and symbolically represent knowledge. A theory may be as lacking for information as for know-how.⁶

⁶Contrary to Dreyfus' and Dreyfus' doubts, the organization behaviorists, Argyris and Schoen (1978, p. 11), believe it possible to derive the "theory-in-use" from "directly observable data of behavior...to ground...construction of the models of action theories which guide interpersonal behavior."

	Individual	Group	Organization	Network
Information	-facts	-who knows what	-profits -accounting data -formal & informal structure	-prices -whom to contact -who has what
Know-how	-skill of how to communicate -problem solving	-recipes of organizing such as Taylorist methods or craft production	-higher-order organizing principles of how to coordinate groups and transfer knowledge	-how to cooperate -how to sell and buy

FIGURE 2.

Though codifiability is a central characteristic, it does not capture other aspects of knowledge. Knowledge can vary in complexity. There are many ways to define complexity. From a computer science perspective, it can be defined as the number of operations (or CPU time) required to solve a task. Indeed, Simon's notion of nearly decomposable systems is closely related. An ordered system reduces the cost and necessity of complex communication patterns. Drawing upon information theory, Pringle (1951) draws the distinction between order and complexity, defining the latter as the number of parameters to define a system. Within any given ordering (or what we call a code), complexity can be accommodated, but at a cost.

These dimensions are not independent. Codifiability and complexity are related, though not identical. To return to Pringle's definition, it is obvious that the number of parameters required to define, say, a production system is dependent upon the choice of mathematical approaches or programming languages. For a particular code, the costs of transferring a technology will vary with its complexity. A change of code changes the degree of complexity.

Transformation of Personal to Social Knowledge

The final element in our characterization of the static properties of organizational knowledge is the distinction between the knowledge of an individual and that of the organization. Any discussion of firm knowledge confronts, ultimately, the problem of unit of analysis. We leave to the side the important task of specifying a more explicit integration of individual and organizational knowledge (such as via a shared culture, mechanisms of socialization, or an assumption of affiliative needs), but turn rather to laying out a description of the problem by distinguishing between personal, group, organizational, and network knowledge. The following discussion is summarized in Figure 2.⁷

Nelson and Winter (1982) have provided an important contribution by separating skills from routines. Individuals can be skilled in certain activities, such as driving a car or playing tennis. These skills may indeed be difficult to pass on. Variations in human intelligence alone may render difficult the transfer of technology, especially if intelligence is decomposed into aptitudes for solving differentiated tasks.

⁷As a way of summarizing our argument, this figure was suggested to us by Gunnar Hedlund. See also Hedlund and Nonaka (1991).

It is, in fact, the problem of communicating personal skills that underlies Polanyi's (1966) well-known idea of tacit knowledge, an idea similar to the dimensions of noncodifiable and complex knowledge. As noted earlier, to Polanyi, the central puzzle is the following: why do individuals know more than they can express. An interpretation of his argument is that tacit knowledge consists of search rules, or heuristics, that identify the problem and the elements consisting of the solution (Polanyi 1966, pp. 23–24). The act of solving a problem rests on a sense of how the phenomena function; the formal expression of the solution is unlikely to capture fully this procedural knowledge, or even the data and information (or clues, as Polanyi describes it) leading to the solution. Thus, even in the arena of problem identification and solving, the know-how of heuristic search precedes the formal knowledge of the solution.⁸

The teaching of know-how and information requires frequently interaction within small groups, often through the development of a unique language or code. Part of the knowledge of a group is simply knowing the information who knows what. But it also consists of how activities are to be organized, e.g., by Taylorist principles.

It is the sharing of a common stock of knowledge, both technical and organizational, that facilitates the transfer of knowledge within groups. This view is widely held across a disparate literature. Arrow (1974) views one of the advantages of the organization as its ability to economize in communication through a common code. Piore (1985, p. xxv) likens the theory of internal labor markets to a "conception of production knowledge as being like a language" common to a particular group of workers. By shared coding schemes, personal knowledge can be transmitted effectively within close-knit groups (Katz and Kahn 1966). Personal knowledge can be transmitted because a set of values are learned, permitting a shared language by which to communicate (Berger and Luckman 1967). It is this language which provides a normative sanction of how activities are to be organized or what information is to be collected and evaluated.

But whereas the accumulation of small group interactions facilitate the creation of shared coding schemes within functions, a fundamental problem arises in the shifting of technologies from research groups to manufacturing and marketing (Dougherty forthcoming). At this point, the identification with a professional orientation conflicts with the need to integrate within the organization. The problems of different professional languages are attenuated when technology transfer is horizontal, that is, within the same function, as when a second plant identical to the first is built. To facilitate this communication, certain individuals play pivotal roles as boundary spanners, both within the firm as well as between firms (Allen and Cohen 1969; Tushman 1977).

The vertical transfer of technology, as when a product is moved from development to production, poses additional problems insofar that the shared codes of functional groups differ. Leonard-Barton's (1988) finding that technology transfer success is dependent upon the mutual adaptation between the two parties highlights the critical transformation of personal and group knowledge in the process of codification. To facilitate this transfer, a set of higher-order organizing principles act as mechanisms by which to codify technologies into a language accessible to a wider circle of individuals. These principles establish how the innovation is transferred to other groups, the responsibility of engineers to respond to complaints, and the allocation of incentives to establish authority over decisions. These organizing principles, which we

⁸In the philosophy of the science, this distinction corresponds to the difference between the logic of discovery and the logic of demonstration. See also Dreyfus and Dreyfus (1988) for a discussion in relation to artificial intelligence.

call higher-order as they facilitate the integration of the entire organization, are also supported by data regarding profitability, costs, or task responsibility (as represented in an organizational chart).

In this sense, a firm's functional knowledge is nested within a higher-order set of recipes that act as organizing principles. Complex organizations exist as communities within which varieties of functional expertise can be communicated and combined by a common language and organizing principles. To the extent that close integration within a supplier or buyer network is required, long-term relationships embed future transactions within a learned and shared code. In fact, the trading of know-how among firms often requires the establishment of long-term relationships (von Hippel 1988). In this wider perspective, a firm's knowledge consists also of the information of other actors in the network, as well as the procedures by which resources are gained and transactions and cooperation are conducted.

The Paradox of Replication

There is an important implication for the growth of the firm in the transformation of technical knowledge into a code understood by a wide set of users. An individual is a resource severely restrained by physical and mental limitations. Unless able to train large numbers of individuals or to transform skills into organizing principles, the craft shop is forever simply a shop. The speed of replication of knowledge determines the rate of growth; control over its diffusion deters competitive erosion of the market position.

For a firm to grow, it must develop organizing principles and a widely-held and shared code by which to orchestrate large numbers of people and, potentially, varied functions. Whereas the advantages of reducing the costs of intra- or inter-firm technology transfer encourage codification of knowledge, such codification runs the risk of encouraging imitation. It is in this paradox that the firm faces a fundamental dilemma.

The problems of the growth of the firm are directly related to the issues of technology transfer and imitation. Once organizing principles replace individual skills of the entrepreneur, they serve as organizational instructions for future growth. Technology transfer is, from this perspective, the replication of existing activities. The goal of the firm is to reduce the costs of this transfer while preserving the quality and value of the technology.

Because personal and small group knowledge is expensive to re-create, firms may desire to codify and simplify such knowledge as to be accessible to the wider organization, as well as to external users. It is an interesting point, with far-reaching implications, that such a translation rarely occurs without a transformation in the nature of the knowledge. Computer software packages not only reduce the complexity of the knowledge required to use a computer's hardware; knowing how to use software is, in fact, substantively different from knowing how the computer works.

The reason why software has been successful is that it is codified so as to demand a lower fixed cost on the part of the general user. The user is required to understand the function of the program without knowledge of the substantive technology. (A function is an attribute to the product; substantive technology is the knowledge by which the product is created or produced.) The cost of this transformation is that the user's choices are restricted to the expressed functions. The specificity of a software language cannot expand the capabilities of the hardware; rather, it can only reduce the costs of its accessibility. It is, in fact, the possibility to separate the expertise to generate the technology and the ability to use it that permits the nesting of a firm's knowledge, as described above. But it is also this separation, as discussed below, that

facilitates the ease of imitation. Being taught the functional skills of how to do something is different than being taught how to create it. We turn to these static and dynamic considerations below.

Combinative Capabilities

The issue of being able to use and being able to create software reflects a distinction commonly made in the literature on technology transfer regarding know-how and know-why.⁹ It is, in fact, this distinction between exploiting and developing capabilities that lies at the foundation of Rosenberg's (1976) observation that "reliance on borrowed technology (by developing countries) perpetuates a posture of dependency and passivity." For example, activities involved in a manufacturing production process can be codified and imitated without requiring the knowledge of how the machinery functions. A Japanese factory shop might, conceivably, be organized by rules for inventory management and these rules might be transferred to American operations. Yet, the knowledge that leads to the development of such practices is unlikely to be transferred as easily. Being taught the functional skills of how to do something is different than being taught how to create it.

To return to the development of software as a problem in codifying knowledge, Papert (1979, p. 77) notes the paradox that some languages are simple to learn but become complex in application. He writes:

But what do we mean by 'simpler' and what do we mean by 'learn the language'? Indeed, the (user)...would learn its vocabulary very quickly, but they would spend the rest of their time struggling with its constraints. They would have to search for devious ways to encode even mildly complex ideas into this small vocabulary. Thus it is well-known that the programming language BASIC...is quickly learned, but its programs quickly become labyrinths.

Papert's objection raises two important points. Some codes may be qualitatively better than others. They might facilitate certain technologies or practices better; the language of chemical pharmaceuticals may be inadequate for the development and transfer of biotechnologies. Even for the same technology, some firms may have evolved codes that differ in their efficacy.

The observation that some languages are more "easily learned" suggests, superficially, a contradiction in the argument. Basic is "simpler" but becomes quickly complex. But in what sense is it simpler other than through its familiarity to what the user already knows and through its design to address specific applications familiar to the user? Then why does it become a "labyrinth"? The implicit suggestion is that Basic does not provide an efficient capability to address a change in the required application.

Let us migrate the argument from the individual to the organizational level by sorting out the two issues of familiarity to the user and, as discussed later, of the capability to create new applications to address changes in the environment, such as changes in market demand. Creating new knowledge does not occur in abstraction from current abilities. Rather, new learning, such as innovations, are products of a firm's **combinative capabilities** to generate new applications from existing knowledge. By combinative capabilities, we mean the intersection of the capability of the firm to exploit its knowledge and the unexplored potential of the technology, or what Scherer (1965) originally called the degree of "technological opportunity."

⁹In the interest of avoiding a proliferation of terms, we would add the caveat that since formal science is characterized by recipes through which causal relationships are identified, this distinction may be simply a restatement of the question, identified in footnote 8, whether the methods of scientific discovery can be codified.

In the technological literature, the determinants of "opportunity" are often regarded as physical in character; the speed of electrons is inferior to that of light. But since physical laws are eternally given, the critical question would then seem to be the social laws of their discovery and innovative application. Schumpeter (1968) argued that, in general, innovations are new combinations of existing knowledge and incremental learning.¹⁰ He writes:

To produce other things, or the same things by a different method, means to combine these materials and forces differently . . . Development in our sense is then defined by the carrying out of new combinations (Schumpeter 1934, pp. 65–66).

As widely recognized, firms learn in areas closely related to their existing practice. As the firm moves away from its knowledge base, its probability of success converges to that for a start-up operation (as implicit in Lippman and Rumelt 1982). The abstract explanation for this claim is that the growth of knowledge is experiential, that is, it is the product of localized search as guided by a stable set of heuristics, or, in our terminology, know-how and information (Cyert and March 1963, Nelson and Winter 1982). It is this local search that generates a condition commonly called "path dependence," that is, the tendency for what a firm is currently doing to persist in the future.

It should be clear that individual limitations in learning new skills are not a sufficient explanation. For even if mature individuals do not relearn—as psychological evidence suggests, an organization may reconstitute its knowledge by recruiting new workers with the requisite skills. The problem of the "inertness" of what an organization knows is not reduceable to individuals, except for the degenerate case of restrictions on the recruitment and retirement of human resources.

What makes the innovative search localized is that "proximate" technologies do not require a change in an organization's recipes of organizing research. If current knowledge is inadequate, it may well be that a firm does not know what changes are required in the existing principles and structure of relationships. Even if identified, they may not be feasible, because the relational structure in the organization would be disturbed. Knowledge advances by recombinations because a firm's capabilities cannot be separated from how it is currently organized.

Selection Environment

Up to now, we have been concerned with explaining the role of organizing principles to facilitate the transfer of technology and ideas within the organization of the firm. The distinction between the ability to produce a product and the capability to generate it is fundamental to broadening our perspective to the competitive conditions of imitation. The ability to build on current technology is instrumental in the deterrence of the imitation of a firm's knowledge by competitors.

Imitation differs from technology transfer in a fundamental sense. Whereas technology transfer is concerned with adapting the technology to the least capable user, the threat of imitation is posed by the most capable competitors. In abstraction from a particular technology, it is, *a priori*, impossible to state in general what aspects of the transformation of ideas into marketable products will deter imitation. No matter which factor, however, is the most important, imitation is impeded by the possession of at least one bottleneck capability, as long as this capability is rewarded in the

¹⁰The view that knowledge can be created only as combinations of what is already known has a long lineage, from Plato's *Meno* to Polanyi's (1966) idea of tacitness.

market.¹¹ This bottleneck can possibly arise through the benefits of reputation among consumers, patent protection, or the exercise of monopoly restrictions.

When these entry-detering benefits are absent, competition switches from traditional elements of market structure to the comparative capabilities of firms to replicate and generate new knowledge. The nature of this competition is frequently characterized as a race between an innovator and the ability of the imitating firm either to reverse engineer and to decode the substantive technology. The growth of the firm is determined by a combination of the speed of technology transfer and of the imitative efforts of rivals.

Reverse engineering is often not a required response by competitors to new innovations. Incumbent competitors may simply respond to new product innovations by relying on other capabilities, such as brand labeling or distribution channels. Of more interest to our concerns, some competitors can imitate the function of the technology without necessitating reverse engineering of the substantive code. (As an example, many distinctive kinds of software can provide a spreadsheet function; the function is imitated, but not the underlying technology.) Many new products are only re-designs (i.e., recombinations) of existing components (Henderson and Clark 1990). In this kind of competition, the need to decipher the elements of the innovator's knowledge that generated the product can be simply bypassed.

In this on-going competition, there is a short-term consideration, i.e., at what speed and cost can a firm replicate its current technology and imitate others. In innovative industries, competition is frequently a question of the speed and efficiency by which diverse groups within a corporation cooperate, a problem exacerbated when multi-functional coordination is required in order to increase transfer times to the market (Dougherty forthcoming). Over time and across multiple products, small differences in efficiencies can generate significant variations in profitability and (as well established in evolutionary biology) survival.

Short-term competitive pressures can, however, draw from the investments required to build new capabilities. The direct effect of selection is on the acceptance and rejection of new products, but indirectly it is operating to reward or to penalize the economic merits of the underlying stock of knowledge.¹² Knowledge, no matter how resistant to imitation, is of little value if it results in products that do not correspond competitively to consumers' wants. Selection on product types acts to develop and retard the capabilities of firms.

The ability to indulge in a forward-looking development of knowledge is strongly contingent on the selection environment. Long-term survival involves a complex tradeoff between current profitability and investing in future capability. Future capabilities are of little value if the firm does not survive. In this sense, we have returned to Papert's concerns. Basic may be a poor language by which to address new applications or changes in the market. But for the student facing a deadline, programming in Basic may have clear survival value.

An important question, then, is the critical balancing between short-term survival and the long-term development of capabilities. A too strong reliance on current profitability can deflect from the wider development of capabilities (Stiglitz 1987). By their ability to buffer internal ventures from an immediate market test, organizations have the possibility to create new capabilities by a process of trial-and-error learning.

Thus luxury is often too exorbitant for companies or, for that matter, developing countries facing strong survival pressures. Yet, because investments in new ways of

¹¹This point is captured in empirical work using the survey results, whereby appropriability is defined as the item that indicates the maximum deterrence to imitation (Levin et al. 1987).

¹²This point, of course, lies at the heart of the genes versus phenotype controversy in biology. See, for example, Dawkins (1976).

doing things are expensive, it is possible for a firm to continue to develop capabilities in ways of doing things which it knows, in the long run, are inferior (Arthur 1989). A too rigid competitive environment, especially in the early years of a firm's development, may impede subsequent performance by retarding a firm's ability to invest in new learning.

The Make Decision and Firm Capabilities

The merits of the above argument can be better evaluated by considering an example. An interesting application is the make-buy question, that is, whether a firm should source a component from the outside or make it internally. The examination of this problem throws into relief how an approach based on the knowledge of the firm differs from a contracting perspective.

It has become standard to argue that markets for the exchange of technology fail because of an appeal to a poker-hand metaphor; once the cards are revealed, imitation rapidly ensues since draws from the deck are costless. Because of the work of Teece (1977), Mansfield, Schwartz, and Wagner (1981), and Levin et al. (1987), it is widely recognized this argument is a shibboleth. Yet, the consequences of this recognition are scarcely to be seen in the literature on technology transfer.

In fact, the costliness of its transfer has often been reconstrued as market failure (Teece 1980). Because a buyer cannot ascertain its value by observation, technology cannot be priced out. Thus, markets fail for the selling of technology since it is costly to transact.

The problem of this market failure argument is not only that markets for technology do exist, but also that it is over-determined. The public good argument turns on the opportunism of the buyer; the costs of transfer do not necessitate a similar behavioral assumption, though one can always throw it in for good measure. Opportunism is not a necessary condition to explain why technology is transferred within a firm instead of the market. Rather, the issue becomes why and when are the costs of transfer of technology lower inside the firm than alternatives in the market, independent of contractual hazards. The relevant market comparison, in this sense, are the efficiencies of other firms.

This issue extends to the more commonly studied case of contractual hazards affecting the make or buy decision, that is, whether to source from outside the firm. In the seminal empirical study of Walker and Weber (1984), evidence was found for the claim that the transaction costs of relying on outside suppliers lead to decisions to source internally. Yet, the most important variable is the indicator of differential firm capabilities, that is, whether the firm or the supplier has the lower production costs. Transaction cost considerations matter but are subsidiary to whether a firm or other suppliers are more efficient in the production of the component.

In the Monteverde and Teece (1982) paper that also supported the transaction cost argument, the most significant variable is the dummy for the firm. In other words, despite controls, the heterogeneous and unobserved firm effects were the dominant influence on the make-buy decision. Yet, both firms faced the same environment and transactional hazards.

While the boundaries of the firm are, unquestionably, influenced by transactional dilemmas, the question of capabilities points the analysis to understanding why organizations differ in their performance. The decision which capabilities to maintain and develop is influenced by the current knowledge of the firm and the expectation of the economic gain from exploring the opportunities in new technologies and organizing principles as platforms into future market developments. (See Figure 1.) We

propose that firms maintain those capabilities in-house that are expected to lead to recombinations of economic value.

The evaluation of this economic gain rests critically upon a firm's ability to create and transfer technology more quickly than it is imitated in the market. Many investment decisions inside a firm do not include a make-buy calculation, for the presumption is that the new assets are extensions, or combinations, of the existing knowledge base.¹³ Nor should it be surprising that there is a sense of ownership over the right to make and control the investment, for the physical assets are embedded within the replication of the existing social relationships and political structure of the firm. Because these relationships exist, an ongoing firm should have a greater capability to expand in current businesses than new entrants.

Path dependence is a rephrasing of the simple statement that firms persist in making what they have made in the past; for existing firms, knowledge advances on the basis of its current information and ways of doing things. To return to the Monteverde and Teece study, the finding that firms tended to produce internally those parts with high engineering content is a confirmation that auto companies specialize in engineering design and production. They make those parts that reflect their knowledge. (In fact, we should expect that they imitate those technologies which correspond closely to their knowledge.)

There are, of course, investment opportunities which are uncertain in terms of the applicability of a firm's current knowledge. Internal development, and imitation, are deterred because the organizing principles and information cannot be easily identified. Thus, investments in new knowledge often have a characteristic of trial-and-error learning, much like buying options on future opportunities.

Joint ventures frequently serve as options on new markets distantly related to current knowledge by providing a vehicle by which firms transfer and combine their organizationally-embedded learning. A common purpose of joint ventures is to experiment with new ways by which relationships are structured. That they frequently end by acquisition is a statement of their value as an ongoing entity of enduring social relationships which serve as platforms into new markets (Kogut 1991).

The decision to make or buy is, thus, dependent upon three elements: how good a firm is currently at **doing** something, how good it is at **learning** specific capabilities, and the value of these capabilities as **platforms** into new markets. To formalize the implications of these elements in terms of propositions, we would expect the following to hold:

1. Firms make those components that require a production knowledge similar to their current organizing principles and information.
2. The purchasing of technologies is carried out by the market when suppliers have superior knowledge which is complex and difficult to codify; by licensing when the transferred knowledge is close to current practice.
3. Firms develop internally projects that build related capabilities leading to platforms into new markets or rely on joint ventures (or acquisitions) when the capabilities are distantly related.
4. Immediate survival pressures encourage firms towards a policy of buying.

Similar propositions could be made in reference to other applications, such as acquisitions, the composition of a technology portfolio, and the sequence by which a firm invests in a foreign market.

¹³We would like to thank Gordon Walker for emphasizing that many new investment decisions entail only whether to and not to make internally; there is often no external evaluation.

Conclusions

The study of the knowledge of a firm raises issues, such as relatedness, technical core, or corporate culture, that are familiar to organizational theorists, but that have been hard to pin down. To a large extent, the theory of firm knowledge, as we have sketched it above, neglects the problem of individual motivation by focusing on organizing principles as the primary unit of analysis for understanding the variation in firm performance and growth. Because these principles are expressions of how a firm organizes its activities, they represent the procedures by which social relations are recreated and coordinated in an organizational context.

In contrast to a perspective based on the failure to align incentives in a market as an explanation for the firm, we began with the view that firms are a repository of capabilities, as determined by the social knowledge embedded in enduring individual relationships structured by organizing principles. Switching to new capabilities is difficult, as neither the knowledge embedded in the current relationships and principles is well understood, nor the social fabric required to support the new learning known. It is the stability of these relationships that generates the characteristics of inertia in a firm's capabilities.

Without question, there are issues, such as the creation of compatible incentives to induce behavior from individuals in accordance with the welfare of the organization, that can be fruitfully examined from a contracting perspective. But the transaction as the unit of analysis is an insufficient vehicle by which to examine organizational capabilities, because these capabilities are a composite of individual and social knowledge. After nearly two decades of research in organizational and market failure, it is time to investigate what organizations do.

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