Chapter 16

TECHNOLOGICAL INNOVATION AND THE THEORY OF THE FIRM: THE ROLE OF ENTERPRISE-LEVEL KNOWLEDGE, COMPLEMENTARITIES, AND (DYNAMIC) CAPABILITIES

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Handbooks in Economics, Volume 01

DOI: 10.1016/S0169-7218(10)01016-6

Abstract

The firm is the central actor for the effectuation of innovation and technological change. The large industrial laboratories of the previous century have given way to more organizationally and geographically diffuse sources of technology, placing even greater emphasis on the coordination skills of managers. Dynamic capabilities are the skills, procedures, organizational structures, and decision rules that firms utilize to create and capture value. Managers must be able to sense opportunities, craft a business model to capitalize on them, and reconfigure their organizations, and sometimes their industries, as the business environment and technology shift. The key employees in this regard are experts (literati and numerati), whose management requires limited hierarchy, flexible teams, and performance-based incentives. To encompass these realities, the theory of the firm needs to be augmented to account for opportunity as well as opportunism, coordination beyond the boundaries of the firm as well as within it, variations in the level of capability across firms, and the frequent superiority of the firm over markets for the creation, transfer, and protection of intangible assets. Complementarities and cospecialization are advanced as two emerging concepts of particular relevance to a theory of the innovating enterprise earning above-normal returns.

Keywords

appropriability, business ecosystems, cospecialization, creativity, dynamic capabilities, entrepreneurs, hierarchy, innovation, intangible assets, literati, numerati, organizational structure, strategic management, transaction costs

1. Introduction

The advanced economies of Europe and the United States have gone through a significant transformation over the last half-century. The industrial age, characterized by a supply driven logic (build it and the customers will come) and relying on mass production has given way[1] to more customer-centric logic,[2] characterized by better customer information, rapid feedback cycles, and denser interfirm relationships. At the same time, the organization of innovation is being transformed by an increase in the geographic and organizational diversity of the sources of productive knowledge,[3] and by new ways of organizing.

In innovation-driven economies intangible assets, including relationship capital, are critical to the creation and production of new goods and services. In such economies, it is well recognized that the firm is a key, if not the most important, institution, through which technological change is effectuated. Despite the stark reality of this situation, the economic theory of the firm is still, as Rosenberg (1982) pointed out more than a quarter century ago, a "black box," when it comes to displaying (and understanding) the processes which result in the creation of new products and services and their profitable commercialization. Economics as a discipline may have had success with developing an understanding of the consequences of technological change, but the firm-level and market determinants are still enigmatic.

While the business enterprise plays a large role in determining the rate, direction, and nature of the commercially relevant technological change, the firm's ecosystem, including supporting institutions and legal structures, remains of great importance too, but is omitted in much theorizing about enterprise performance. Likewise, economic theories of the firm often blot out considerations of capability augmentation, technology transfer, and management, despite their great importance in today's industrial landscape. In particular, technology-driven firms have had to face the problem of how to manage and integrate the output of highly skilled experts (*literati* and *numerati*) across countries, time zones, and organizational boundaries. Management involves not only motivating talent and ensuring the job gets done; there is also a strategic component—what tasks to assign, what priorities to set, what resources to use, and where to get them from. To respond to these challenges, business enterprises need to develop capabilities and deploy them on a global basis. Economic theory has barely begun to recognize this.

This chapter does not attempt to survey the economics of technological change for which there is now a large literature. Instead, discussion is restricted to more neglected topics that relate primarily to innovative activities and their management inside the firm. These include:

[1] See Piore and Sabel (1984) who were among the first to trumpet the end of mass production.

[2] Today's era is not one in which big business has to be held in check by big labor, as Galbraith (1952) claimed was necessary; rather big business is held in check by customers who have choices, and by small businesses that compete with them, using domestic or offshore production bases. Global competition and dispersion in enterprise capabilities has enabled these trends. Because of these developments, large-scale established firms like Citibank, IBM, AT&T, Sears and General Motors have had their very existence threatened; and they are transforming in order to survive. Meanwhile, companies with barely a quarter century of history, like Apple, Cisco, Dell, Google, Microsoft, and Wal-Mart are now very significant firms on the industrial landscape. In this new world, entrants, not incumbents, tend to create most of the new jobs.

[3] See, for example, Teece (2000). There is no doubt that technological innovation is the primary driver of economic growth and was also critical to the outcomes in both world wars.

1. A historical sketch of R&D and innovative activities by firms over the past 100 years, describing at a general level how the organizational model associated with R&D activity in the private sector has changed over the past century.
2. The landscape in which firms innovate, including the institutional setting, market structure (which has attracted inordinate attention from economists), and the technology environment.
3. An introduction to the concept of the firm's capabilities and the dynamic capabilities framework.
4. Notes on the internal structures and incentives conducive to innovation, including the management of experts.
5. A theory of the innovating firm; how the firm not only solves contracting problems but also develops and deploys capabilities for the creation and management of know-how. The theory of the innovating firm advanced here does not displace transaction cost theory. Rather it builds a capabilities dimension into the Coase-Williamson theory of the firm.

2. The organization and environment of enterprise-level R&D

In the advanced economies of North America, Europe, and Asia, the business firm is at the core of the system of technological innovation.[4] The emergence and growth of industrial research and development (R&D) during the twentieth century, first in the United States and later in Europe, must rank as one of the most important economic developments in modern history.[5]

This enterprise-level R&D has steadily evolved in response to competitive opportunities and pressures. Its internal organization and relation to external actors have changed completely. Today, innovation takes place in a transformed global landscape from that of a century, or even 20 years, ago.

Industrial R&D is the activity in which the talents of scientists and/or engineers, the numerati, are harnessed to create new products, processes, and services. "R&D" encompasses several classes of activities that can occur in any order and across multiple organizations. There is basic research, which is aimed purely at the creation of new knowledge. Its purpose is to create new understandings of phenomena. There is applied research, which is work expected to have a practical, but not a commercial, payoff. Development is when the technologies behind a product or service are integrated and honed toward commercial application. Boundaries among these activities are quite fuzzy, and the manner in which they have been organized and linked has changed over time.

The roots of (American) industrial research can be found in the early nineteenth century when independent inventors like Eli Whitney (cotton gin) and Charles Goodyear (vulcanization of rubber) set out to commercialize their own inventions, often earning only meager profits. Later in the century, science began to be applied to industries such as dyestuffs, chemicals, electricity, and telecommunications.

Corporate research laboratories first appeared in the German chemical industry in the late nineteenth century, following the enactment of strong patent protection that put a stop to rampant imitation

[4] This is not to discount the critical role of supporting institutions as discussed in Nelson (1993) and elsewhere, but the emphasis in this chapter is on the internal operations of the firm.

[5] More detailed accounts of this history can be found in Mowery and Rosenberg (1989) and Hounshell (1996).

(Hounshell and Smith, 1988, p. 4). The first organized research laboratory in the United States was established by the inventor Thomas Edison in 1876. In 1886, an applied scientist by the name of Arthur D. Little started his firm, which became a major technical services/consulting firm to other enterprises.

Corporate laboratories on the German model began to appear in the United States soon after the Sherman Antitrust Act of 1890 steered companies to look for new ways to gain an advantage over rivals. Significant R&D labs were founded in the years before World War I at Eastman Kodak (1893), B.F. Goodrich (1895), General Electric (1900), Dow (1900), DuPont (1902), Goodyear (1909), and American Telephone and Telegraph (AT&T; 1907).

Independent research organizations like Arthur D. Little and the Mellon Institute continued to grow during the early twentieth century, but were surpassed by the rapid expansion of in-house research (Mowery, 1983). However, the many technology contracting problems and the efficiencies achievable from integration with manufacturing meant that external R&D could only serve as a complement, not a substitute, for in-house research (Armour and Teece, 1980).

The founding of formal R&D programs and laboratories stemmed in part from competitive threats. For instance, AT&T at first followed the telegraph industry's practice of relying on the market for—that is, it outsourced—technological innovation. However, the expiration of the major Bell patents and the growth of large numbers of independent telephone companies helped stimulate AT&T to organize Bell Labs to generate inventions and innovations internally. Competition likewise drove George Eastman to establish laboratories at Kodak Park in Rochester, New York, to counteract efforts by German dyestuff and chemical firms to enter into the manufacture of photographic chemicals and film.

During the early years of the twentieth century, the number of research labs grew dramatically. By World War I there were perhaps as many as one hundred industrial research laboratories in the United States. The number tripled during World War I, and industrial R&D even maintained its momentum during the Great Depression. The number of scientists and research engineers employed by these laboratories grew from 2775 in 1921 to almost 30,000 by 1940.

The interwar period saw some of the labs make significant advances in basic research. In 1927, Clinton Davisson began his work at Bell Labs on electron diffraction. His work led to a Nobel Prize in physics in 1937. At DuPont, Wallace Carothers developed and published the general theory of polymers, and went on in 1930 to create synthetic rubber, and then a strong, tough, water-resistant fiber called nylon. These technological breakthroughs were in and of themselves of great importance, but it took time and money to leverage them into marketable products. For instance, over a decade elapsed from the beginning of research in super polymers to the production of nylon on commercial terms.

Building on wartime success, including the Manhattan Project (to create the atomic bomb), the era of big science began after World War II, fueled by the optimism that well-funded scientists and engineers could produce technological breakthroughs that would benefit the economy and society. University scientists, working together with the engineers from corporate America, had indeed produced a string of breakthrough technologies including radar, antibiotics, the digital electronic computer, and atomic energy. The dominant intellectual belief of the immediate postwar period was that science-driven research programs would ensure the development of an endless frontier of new products and processes. The development of the transistor at Bell Labs gave strength to this view, and many firms augmented their commitments to industrial R&D, including a small portion of purely basic research. In 1956, IBM established a research division whose mandate included world-class basic research.

As international tensions increased during the Cold War, government funding grew considerably. In 1957, government funding of R&D performed by industry eclipsed the funding provided by the firms themselves. By 1967, it went back the other way, with private funding taking the lead. By 1975, industry funding of industry-conducted R&D was twice the federal level and the ratio was expanding.

Government procurement was perhaps even more important to the technological development of certain industries, as it facilitated early investment in product facilities, thus easing the cost of commercialization. The newly emergent electronics industry in particular was able to benefit from the Defense Department's demand for advanced products. By 1960, the US electronics industry had come to rely on the federal government for 70% of its R&D dollars (which may have cost US firms their leadership in consumer electronics as they became preoccupied with the more performance-oriented requirements of the US military).

By the early 1970s, management was beginning to lose faith in the science-driven approach to innovation, primarily because few blockbuster products had emerged from the research funded during the 1950–1970s. Competition became more global, leaving firms less certain of cash flow from their domestic market for funding R&D. New technology was not converted into new products and processes rapidly enough, confronting many companies with the paradox of being leaders in R&D and laggards in the introduction of innovative products and processes. The fruit of much R&D was appropriated by domestic and foreign competitors, and much technology languished in research laboratories. In telecommunications, Bell Labs' contribution to the economy at large far outstripped its contribution to AT&T. In the semiconductor industry, Fairchild's large research organization contributed more to the economy through the spin-off companies it spawned than to its parent. Xerox Corporation's Palo Alto Research Center made stunning contributions to the economy in the area of the personal computer, local area networks, and the graphical user interface that became the basis of Apple's Macintosh computer (and, later, of Microsoft's Windows). Xerox shareholders were well served too, but most of the benefits ended up in the hands of Xerox's competitors or of companies in adjacent industries.

Different modes of organization and different funding priorities were needed. Knowledge throughout the firm had to be embedded in new products promptly placed into the marketplace. A new way of conducting R&D and commercializing new products was needed.

By the 1980s and 1990s, a new model for organizing research became apparent. First, inside large corporations, R&D activity came to be decentralized, with the aim of bringing it closer to users and customers. By the mid-1990s, Intel, the world leader in microprocessors, was spending over $1 billion per year on R&D, yet did not have a separate R&D laboratory. Rather, development was conducted in the manufacturing facilities. Intel did not invest in fundamental research at all apart from its funding of university research and some research activities located on or near university campuses.

Second, many companies were looking to the universities for much of their basic or fundamental research, maintaining close associations with the science and engineering departments at the major research universities. Indeed, the percentage of academic research funded by industry, which had declined to 2.5% by 1966, rose steadily to 7.4% in 1999, declining since then to about 5%, its level in the early 1980s (National Science Board, 2008, Appendix Table 4-3). Strong links between university research and industrial research are present in electronics (especially semiconductors), chemical products, medicine, and agriculture. For the most part, university researchers are insufficiently versed in the particulars of specific product markets and customer needs to help configure products to the needs of the market.

Third, corporations have embraced horizontal, vertical, and lateral alliances involving R&D, manufacturing, and marketing in order to get products to market quicker and leverage off complementary assets and capabilities already in place elsewhere. A variant on this strategy is the new product-oriented corporate acquisition, employed as a vital complement to in-house R&D, perhaps most notably by Cisco, which has spent billions to acquire dozens of companies with products that had been recently placed into the market (Mayer and Kenney, 2004). It is important to note, however, that outsourced R&D is a complement, not a substitute, to in-house activities. Outsourcing and codevelopment arrangements had become common by the 1980s and 1990s (e.g., Pratt & Whitney's codevelopment programs for jet engines, or the IBM-Sony-Toshiba alliance for the development of the Cell processor) as the costs of product development increased, especially after the antitrust laws were modified to recognize the benefits of cooperation in R&D and related activities. Cooperation was also facilitated by the emergence of capable potential partners in Europe and Japan.

These developments meant that at the end of the twentieth century, R&D was being conducted in quite a different manner from how it was organized at the beginning. Many corporations had closed, or dramatically scaled back, their central research laboratories, including Westinghouse, RCA, AT&T, US Steel, and Unocal to name just a few. Alliances and cooperative efforts of all kinds were of much greater importance.[6] Many firms are now sourcing much of their innovation externally, following an "open" innovation model (Chesbrough, 2006).

Moreover, much of the momentum for commercializing innovations had shifted to venture capital-funded "start-ups." By the 1980s, private venture funds began to have a transformative effect on the US industrial landscape, particularly in biotech and information technology. They dramatically increased the funds that were available to, as well as the professionalism of, entrepreneurs.

In many ways these new, agile venture-funded enterprises still depended on the organized R&D labs for their birthright. Some start-ups were exploiting technological opportunities that incumbents had considered and rejected.

The long lead time needed to commercialize early stage research (and the potential for leakage to domestic and foreign rivals) was difficult for management to justify. Venture funds were also generally uninterested in funding exploratory research. This has left basic and applied research in some sectors (like communications) with a diminished funding base. Some observers fear that society is "eating its seed corn."[7]

The organization of R&D in the last half-century also becomes multinational in scope.[8] The result is that, by 2000, domestic as well as multinational firms employ numerati and literati in a globally distributed fashion to (1) develop localized products and services closer to offshore users, (2) take advantage of specialized sources of creativity and innovation, and (3) source development services from low-cost providers. It is particularly noteworthy that, since the late 1990s, United States and European companies have been establishing satellite R&D facilities in China and India at a high rate. However,

[6] Economists generally—and antitrust authorities in particular—have become more receptive to the notion that technology alliances among competing firms can bring societal as well as private benefits (Baumol, 2001; Jorde and Teece, 1990; Katz and Ordover, 1990; Teece, 1992).

[7] Interview with Dr. William Spencer, former head of R&D at Xerox Corporation.

[8] Although the offshore R&D trend has accelerated in recent years with the advent of improved talent pools in industrializing countries, enhanced telecommunications, and liberalized trade, the use of foreign R&D labs has deep roots. See Mansfield et al. (1979).

the trend toward greater globalization should not be exaggerated. Globalization of innovation (as distinct from manufacturing) has not yet been significant in all industries, and it often involves lower level activities based on technologies developed closer to company headquarters.

3. The innovating firm in context

The above short history makes it apparent that firms exist and innovate neither in isolation nor in some "flat" world of uniformly and globally distributed capabilities. Before analyzing the nature and organization of the dynamically innovating firm, one must understand the external factors that affect such firms. Firms operate with a balance—sometimes favorable, sometimes unfavorable—of help or hindrance from domestic and local institutions. Another element of the context for innovation is market structure. The technological environment in which a firm innovates is yet a third cluster of factors which shape (and are shaped by) innovation.

3.1. The ecosystem for innovation

Several important literatures address factors in the firm's external environment which impact firm-level innovative performance. These literatures are not themselves well integrated, and bear labels such as national systems of innovation, regional systems of innovation, clusters, and ecosystems. This section does not attempt to review this literature, but merely highlights some of the key elements.

The basic argument of the literature is that firm-level innovation depends on the supply of skilled workers (who are not entirely mobile internationally), universities (for access to both highly educated talent and faculty research), financial institutions (especially venture capital), the legal system (especially intellectual property law and employment law), the supply base (including complementors), the domestic market, and the presence of other firms in the same or related industries. Figure 1 displays factors and their interaction.

While institutional structures can have national identities, they may have regional identities, too. Work on national and regional systems argues for defining what might be thought of as national and regional business ecosystems supporting innovation (Nelson, 1993). The evidence supporting the concept is considerable, with Silicon Valley being a classic case (Saxenian, 1996).

Economic historians have always given considerable weight to the role of institutions and government in economic growth at the national level (e.g., Abramovitz, 1986; Nelson, 1982), but very few studies connect the performance of particular firms to key elements in the ecosystem. However, vignettes and anecdotes abound. In the US civilian aircraft industry, for example, foreign technology and government procurement were vital inputs to domestic innovation. Boeing and others in the United States accessed developments in jet engine technology that had occurred in the United Kingdom and Germany in the creation of their own aircraft (Phillips, 1971). Boeing leveraged its subsequent success with the KC-130 jet tanker built for the Air Force into a civilian version—the Boeing 707—and captured a lead in global market share that lasted until the emergence and growth of Airbus. The nascent semiconductor industry also benefited from the willingness of the US military to buy advanced products at premium prices.

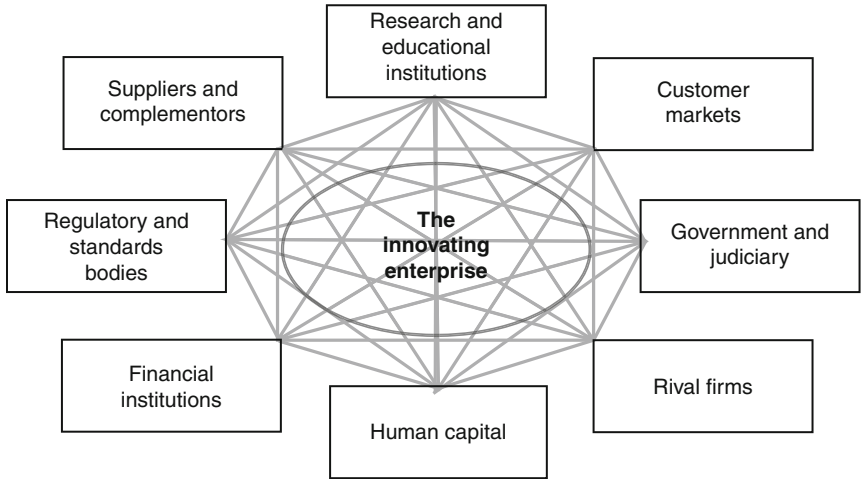

Figure 1. The innovation ecosystem.

Another prominent example of the ecosystem impacting innovation is the Internet. The basic technology and structure of the Internet has its origins in university research applied in the late 1960s by Bolt, Beranek, and Newman, a contractor to the US Department of Defense, to build a network connecting researchers with government contracts to government-sponsored computers in order to maximize resource utilization. ARPANET gradually extended its reach around the world and was merged in 1983 with similar networks to form the Internet.

3.2. Market structure as a determinant of innovation

A less important context for innovation, although one which has received an inordinate amount of attention by economists over the years, is market structure, particularly the degree of market concentration. Indeed, it is not uncommon to find debate about innovation policy among economists collapsing into a rather narrow discussion of the relative virtues of competition and monopoly. Clearly there is much more at work, including the various elements of the ecosystem noted above. Subsequent sections will identify various dimensions of internal firm structure and management that also impact the rate and direction of innovation.

There has been considerable debate and scholarly attention to the role of market structure on determining firm-level innovation. Schumpeter was among the first to declare that perfect competition was incompatible with innovation. The hypothesis often attributed to him (see Schumpeter, 1942, especially Chapter VIII), posits that profits accumulated through the exercise of monopoly power (assumed to be correlated with large firms) are a key source of funds to support risky and costly innovative activity. These predictions, even as a matter of theory, are not well grounded in the financial realities of the firm (Kamien and Schwartz, 1978).

Any theory of market power as a funding mechanism for innovation in specific markets is further unshackled if the multiproduct (multi-industry) firm is admitted onto the economic landscape. The multiproduct structure allows the allocation of cash generated anywhere to be directed to high-yield purposes everywhere inside the firm. The fungibility of cash inside the multiproduct firm thus unlocks any causal relationship between market power (which is a market-specific concept) and innovation.

The Schumpeterian notion that small entrepreneurial firms lack adequate financial resources for innovation seems at odds with his earlier views (1934) on entrepreneur-led innovation and seems archaic in today's circumstances where venture capital-funded enterprises play such a large role in innovation (Gompers and Lerner, 2001). From time to time, public equity markets have also funded relatively early stage biotech and Internet companies with minimal revenues and negative earnings.

Another setback for the various Schumpeterian market structure-innovation hypotheses is that the logic can run the other way: namely, that innovation shapes market structure. Success garnered from innovation can lead to market concentration, as it has with Intel and Microsoft, and as it once did with the Ford Motor Company and Xerox.

Various reviews of the extensive literature on innovation and market structure generally find that the relationship is weak or holds only when controlling for particular circumstances (Cohen and Levin, 1989; Gilbert, 2006; Sutton, 2001). The emerging consensus (Dasgupta and Stiglitz, 1980; Futia, 1980; Levin and Reiss, 1984, 1988; Levin et al., 1985; Nelson and Winter, 1978) is that market concentration and innovation activity most probably either coevolve (Metcaffe and Gibbons, 1988) or are simultaneously determined. Context (stage in the industry life cycle; technological environment) is likely to matter.

3.3. The technological environment

An important consideration shaping innovation is the technological environment that surrounds and shapes the firm's technological activity.

One prominent feature of the environment is the abundance (or scarcity) of technological opportunities. In an industry with lots of technological opportunities, innovation is expected to be relatively easy due to a lower expected development cost and/or a plentiful supply of relevant and available knowledge. For example, university and government (funded) research in science and technology help create vibrant technological environments with multiple sources of new technology, fueling venture-funded new businesses. Biotech is a case where US government funds distributed through the National Institutes of Health have helped to create technological opportunities which are then seized upon and developed further by new venture-funded startups. While most of these companies fail, enough survive to impact the structure of the pharmaceutical industry.

Technology opportunities may shed light on the market structure enigma from the previous section. A leading textbook (Scherer and Ross, 1990, p. 645) notes that "the structure-to-innovation linkage probably operated over a much shorter time span than the innovation-to-structure linkage." This second linkage is expected to be stronger in industries with rich technology opportunities. The idea is that concentration is more conducive to innovation in slow-moving fields, whereas technological opportunity, which can give rise to radical breakthroughs, favors newcomers, not incumbents. These refinements seem plausible; however, recent empirical work suggests that the relationship between technological opportunities and market leadership are far from straightforward (Fai, 2007).

A broader concept than "technological opportunities" is that of "technological regimes." Nelson and Winter (1982) claimed that knowledge and opportunity are determined by the underlying "technological regime" (p. 258). Studies have identified various types of technological regimes without settling on a common definition (Acs and Audretsch, 1990; Malerba and Orsenigo, 1993; Pavitt et al., 1987; Shane, 2001; Winter, 1984). Variables that have been considered in these studies include technological opportunity, the stage of the technology's life cycle, appropriability, cumulativeness, complexity, and capital requirements.

Across the range of opportunities encompassed by a given technological regime, innovation tends to occur along trajectories within a technological paradigm (Dosi, 1982; Teece, 2008).[9] The paradigm includes a definition of those problems currently identified as important and the patterns of solutions (principles) that should be applied. To this, firms bring their internal routines and other tacit knowledge for problem solving, but the paradigm serves as a (soft) constraint on the innovations likely to occur, until a disruptive innovation leads to a new paradigm.

Just how and why some firms tap into technological opportunities remains somewhat enigmatic; the microanalytics of these decisions are not well explained by economic theory, or by any other theory for that matter. The various economic theories of innovation pay very little attention to factors inside the firm. An effort to remedy the situation is commenced in the next section.

4. Resources, competences, and dynamic capabilities

To better understand the nature of the innovating firm, several concepts developed in the strategic management literature are relevant. However, the terminology of resources, competences, and capabilities has never been standardized. To reduce confusion, this section defines the key terms used in this chapter.

4.1. Resources/competences

Resources are firm-specific assets that are difficult, or impossible, to imitate. They are stocks, not flows. They could be tangible but are more likely to be intangible. Such assets are idiosyncratic in nature, and are difficult to trade because their property rights are likely to have fuzzy boundaries and their value is context dependent. As a result, there is unlikely to be a well-developed market for resources/competences; in fact, they are typically not traded at all. They are also generally difficult to transfer among firms. Examples include intellectual property, process know-how, customer relationships, and the knowledge possessed by groups of especially skilled employees.[10]

[9] This notion of a consensus-based technology trajectory lies in the background of a common innovation model in economics, the patent race (e.g., Reinganum, 1981).

[10] While the industrial workforce has always contained individuals with high education and/or exceptional talent, the economic significance of such literati and numerati has become more important as the traditional sources of firm profitability have been undermined (Albert and Bradley, 1997, p. 4). The nature and management of the firm's "expert talent" are discussed below in Section 6.

Competences are a particular kind of organizational resource. They result from activities that are performed repetitively, or quasi-repetitively. Organizational competences enable economic tasks to be performed that require collective effort. Organizational competences are usually underpinned by organizational processes/routines. Indeed, they represent distinct bundles of organizational routines and problem-solving skills.[11]

In short, ordinary competence defines sufficiency in performance of a delineated organizational task. It is about doing things well enough, or possibly very well, without attention to whether the economic activity is the right thing to do. Competences can be quantified because they can be measured against particular (unchanging) task requirements. The level of a competence can be benchmarked; the assessment of a competence does not require that the activity be aligned with the firm's environment and other assets/competences.

Some processes undergirding competence are formal, others informal. As employees address recurrent tasks, processes become defined. The nature of processes is that they are not meant to change (until they have to). Valuable differentiating processes may include those that define how decisions are made, how customer needs are assessed, and how quality is maintained.

As an organization grows, its capabilities are embedded in competences/resources and shaped by (organizational) values. Organizational values define the implicit norms and rules of the organization. They determine how it sets priorities with respect to how employees and affiliates work together.

While economics has often modeled firms as homogeneous, or asymmetric only in their access to information, the "resource-based view" of the firm recognizes the unique attributes of individual firms. The resources framework has developed in the management literature, building on Penrose (1959), Rubin (1973), and others. In the 1980s, a number of strategic management scholars, including Rumelt (1984), Teece (1980b, 1982, 1984), and Wernerfelt (1984) began theorizing that a firm earns rents from leveraging its unique resources, which are difficult to monetize directly via transactions in intermediate markets. This in turn gave rise to the analysis of learning and knowledge management as the means to develop and augment new, hard-to-imitate resources.

Since markets are a great leveler, firms can build long-term profitability in what we normally think of as competitive markets mainly from the ownership and orchestration of nontradable (intangible) assets. If an asset or its services are traded in a market, it can be accessed by all who can pay. The range of domains in which competitive advantage can be built narrows as more and more activities become outsourceable. The Internet and other recent innovations have vastly expanded the number and type of goods and services that are readily accessed externally.

The set of intangible assets that remains especially difficult—although not impossible—to trade consists of knowledge assets and, more generally, resources. Knowledge assets are tacit to varying degrees and costly to transfer (Teece, 1981). The market for know-how is also riddled with imperfections, which favors internalization to capture strategic value in that certain assets are more valuable to one firm than another. Assets that have such special value are referred to here to as "strategic assets."

A firm's resources, which can include knowledge and intellectual property, are significant potential sources of advantage. As already noted, "resources" are a stock, not a flow. However, resources must be constantly renewed (Teece, 2009). The need for renewal is amplified in fast-moving environments such

[11] Organizational competences have their roots in the work of Simon (1947), Nelson and Winter (1982), Winter (1988), Teece et al. (1994), and Dosi et al. (2000).

as those characteristic of high-tech sectors (e.g., computers). However, a need to renew resources can also occur in "low-tech" industries (e.g., life insurance).

4.2. Resources/competences, "strategic" assets, and price theory

Because the value of a resource/asset is context dependent, the market for such assets is generally thin. Two powerful economic implications follow: when one is able to secure strategic resources/assets through purchase, they may be bought for less than they are worth to the buyer because this may be considerably more than they are worth to the seller (the converse in also true). Put differently, from some perspectives, the market need not fully price strategic assets/resources. Accordingly, "abnormal" or "supernormal" profits can flow, at least for a while, from securing (either by purchase or through "building" internally) such assets.

This situation (i.e., abnormal returns) has its roots not in luck but in the possession of other complementary or cospecialized assets (which creates unique contexts), along with sensing (including search) and seizing (including good execution). The market may not lead to the necessary "coordination." It is well understood that the price system's normal asset allocation role is unlikely to occur properly when asset values depend on idiosyncratic combinations. Achieving such value-enhancing combinations is discussed below under the concept of dynamic capabilities. The entrepreneurial manager, not the Walrasian arbitrageur, achieves the microlevel coordination that economic theory (and the economy) requires.

An implication of this approach is that input or factor markets are not fully efficient. Mainstream price theory expounds the view that with (perfect) competition it is impossible to purchase something for less than it is worth or for less than the long-term costs of producing it. However, and without appealing to monopsony theory, it is often possible to secure (by buying or building) something for less than it is worth (to the buyer/owner) if one has superior information, or if one owns related specific assets for which there is no established market.

Note that thin markets are ubiquitous when one is referencing intangible assets/intellectual property and "resources." Hence, the context in which the phenomenon at hand is common includes situations where intangible assets are used intensively.

Economic theory has yet to recognize these lacunae, and explore implications for the theory of the firm. Hints about what is being articulated here can be found in Richardson (1972) and in the literature on entrepreneurship (e.g., Kirzner, 1997). Teece (1980b, 1981) made the case that the market for know-how—a critical "resource"—was riddled with inefficiencies which would blunt market exchange, and favor internal organization. It is well recognized that it is generally hard for a firm to earn better than a competitive return if factor markets are efficient (Barney, 1986). But, if one uses what Oliver Williamson refers to as "main case reasoning," then the (implicit) "main case" where intangible assets are created, transferred, combined, and used intensively, is that the market is not perfectly competitive and all public information need not be reflected in the prices of specific assets, tangible or intangible.

Even if prices did reflect all information, the thin market phenomenon referenced here would still result in wide bands for "competitive" prices if firms are heterogeneous and innovation and product differentiation are ubiquitous. This is the setup implicitly adopted in the strategic management literature (Denrell et al., 2003; Rumelt et al., 1991; Teece and Winter, 1984). Modern auction theory

(e.g., Klemperer, 2002) likewise recognizes that assets will not achieve their full value in an auction if there is only one buyer. What is missing is an effort to tie these disparate threads in the literature to a theory of the firm. The concept of dynamic capabilities is a framework to move the theory of the firm in that direction.

4.3. Dynamic capabilities

Dynamic Capabilities are the firm's ability to integrate, build, and reconfigure internal and external resources/competences to address and shape rapidly changing business environments (Teece et al., 1997, 1990). The goal is to generate abnormal returns. Dynamic capabilities may sometimes be rooted in certain change routines (e.g., product development along a known trajectory) and analysis (e.g., of investment choices). However, they are more commonly rooted in creative managerial and entrepreneurial acts (e.g., pioneering new markets). They reflect the speed and degree to which the firm's idiosyncratic resources/competences can be aligned and realigned to match the opportunities and requirements of the business environment. An organization with strong dynamic capabilities can achieve abnormal returns because markets do not price them at their value to the buyer if the buyer possesses complementary and, in particular, cospecialized assets.

The essence of resources/competences as well as dynamic capabilities is that they cannot generally be bought; they must be built. As noted above, dynamic capabilities measure the capacity to align and realign, and resources/competences are integrated and reintegrated so that they are tuned to the business environment. Sensing, seizing, and transforming are particular attributes of firms that enable them to evolve and coevolve with the business environment. Such capabilities are critical to long-term profitability (Teece, 2007b).

Sensing and seizing are similar to two activities discussed in the management literature as potentially incompatible inside a single organization: exploration and exploitation (March, 1991). Exploration (e.g., research on a potentially disruptive technology) has a longer time horizon and greater uncertainty than exploitation (e.g., selling mature products). The two types of activities require different management styles; one solution is an "ambidextrous organization" where two separate subunits with different cultures are linked by shared company-wide values and senior managers with a broad view—and appropriate incentives (O'Reilly and Tushman, 2004).

As discussed above, a firm's basic competences, if well honed, enable it to perform efficiently the activities that it sets out to perform. However, whether the enterprise is currently making the right products and addressing the right market segment, or whether its future plans are appropriately matched to consumer needs and technological and competitive opportunities, is determined by its dynamic capabilities. Dynamic capabilities, in turn, require the organization (especially its top management) to develop conjectures, validate them, and realign assets and competences for new requirements. They enable the enterprise to profitably orchestrate its resources, competences, and other assets.

Dynamic capabilities are also used to assess when and how the enterprise is to ally with other enterprises. The expansion of trade has enabled and required greater global specialization. To make the global system of vertical specialization and cospecialization (bilateral dependence) work, there is a need (indeed an enhanced need) for firms to develop and align assets and to combine the various elements of the global value chain so as to develop and deliver a joint "solution" that customers value.[12]

[12] Cospecialization has strong implications for organization and strategy (Teece, 2007a).

Not infrequently, the innovating firm(s) will be required to create a market, such as when an entirely new product is offered to customers, or when new intermediate products must be traded. Dynamic capabilities, particularly the more entrepreneurial competences, are a critical input to the market creating (and cocreating) processes.[13]

To summarize, dynamic capabilities reflect the capacity a firm has to orchestrate activities and resources/assets within the system of global specialization and cospecialization. They also reflect the firm's efforts to create/shape the market in ways that enable value to be created and captured. This often requires extending, modifying, or, if necessary, completely revamping what the enterprise is doing so as to maintain a good fit with (and sometimes to transform) the ecosystem and markets that the enterprise occupies. Microfoundations and organizing principles have been laid out elsewhere (Teece, 2007a). A brief summary is provided below for the major (dynamic) capability categories.

5. A dynamic capabilities view of the firm

5.1. General

As discussed earlier, the proper functioning of an economy experiencing change (whether driven by innovation or anything else) requires resources (including intangible assets) and ordinary competences/capabilities to get the job done (i.e., to produce the products/services customers want and to do so efficiently and expeditiously). Such an economy will also need either a new set of firms to produce what customers want next (and what technology allows next), or it will need existing firms to morph in order to both shape and address new opportunities and threats.

For an existing enterprise, there is a requirement to first identify new opportunities and threats and then to shape and reshape the enterprise—and possibly elements of the market environment itself. The capacity to reengineer the enterprise and its product offerings, its internal activities, and its external relationships is what we mean by dynamic capabilities. Externally, they also involve managing/pacing the coevolution of suppliers, competitors, and complementors.

Dynamic capabilities require entrepreneurial activity; but dynamic capabilities use the current "platform" of the enterprise. Dynamic capabilities are not simply manifestations of "intrapreneurship," although this may be an element. Dynamic capabilities have both external and internal organizational dimensions.

5.2. Innovation and change

Innovation and change are sometimes conceived as a two-step procedure—invention and commercialization (Mansfield, 1974). In fact, Teece (2007a) suggests that it is more realistic to view continuous renewal as requiring an ongoing set of activities and adjustments that can be divided into three clusters: (1) identification and assessment of an opportunity (*sensing*), (2) mobilization of resources to address an opportunity and to capture value from doing so (*seizing*), and (3) continued renewal (*transforming*).

[13] The entrepreneurial creation and cocreation of markets is often required to ensure the appropriability of returns from innovation (Pitelis and Teece, 2009).

Table 1
Activities conducted to create and capture value (organized by clusters of dynamic capabilities)

	Sensing	Seizing	Transforming
Creating value	Spotting opportunities Identifying opportunities for research and development Conceptualizing new customer needs and new business models	Investment discipline Commitment to research and development Building competencies Achieving new combinations	Achieving recombinations
Capturing value	Positioning for first mover and other advantages Determining desirable entry timing	Intellectual property qualification and enforcement; Implementing business models Leveraging complementary assets Investment or coinvestment in "production" facilities	Managing threats Honing the business model Developing new complements

Collectively, these are a firm's *dynamic capabilities*. They are required if the firm is to sustain itself as markets and technologies change.

One could imagine that a market economy would allow individuals and organizations to specialize in one of the three capability clusters. However, the markets for opportunities, inventions, and know-how are riddled with inefficiencies and high transaction costs, and most entrepreneurs are forced to bundle these activities (i.e., do all three).[14]

The relative importance of the competences and adjustment mechanisms that constitute sensing, seizing, and transforming varies according to circumstance. To simplify the analysis of dynamic capabilities even further, they can be grouped into two essential classes of activities: creating value and capturing value (see Table 1).

Dynamic capabilities are most relevant in a regime of rapid change, a condition that prevails in a growing number of industries. The global economy has undergone drastic changes that have accelerated the rhythm at which firms innovate. The decreased cost of communication and data flow, the reduced barriers to trade, and the liberalization of labor and financial markets in many parts of the world are forcing firms to confront agile and/or low-cost competitors early in the product cycle. This in turn has caused firms to undertake a major revision of their innovation strategies, such as the closure or downsizing of large industrial research labs described earlier and a corresponding greater reliance on open innovation.[15]

The following sections present dynamic capabilities in greater detail organized within the subsets of activities related to creating and capturing value.

[14] The market for opportunities is imperfect due both to problems of conveying the merits of ideas and also because of opportunism, which can lead to the "lemons" problem identified by Akerlof (1970). In general, entrepreneurs will be reluctant to "sell" or simply license ideas they believe are undervalued. The outcome thus tends toward internalization. For an early statement of some of these issues, see Teece (1981).

[15] This is in some ways the mirror image of the "Second Industrial Revolution," when earlier improvements to communications (telegraph) and transportation (railroad) induced a period of vertical integration on a continental scale with an emphasis on in-house R&D (Chandler, 1990).

5.3. Creating value with innovation

Despite its obvious importance, a theory of how firms create value is largely missing from the standard economics literature. To the extent it is addressed, the industrial organization literature dwells almost entirely on the funding of R&D, figuring (implicitly) that the R&D expenditure is the main driver of innovation. However, R&D activity is only one of several factors likely to determine the generation of new ideas.[16] The concept of dynamic capabilities—the sensing, seizing, and transformation that ongoing innovation requires—provides a broader framework to help one understand how firms create value.

Sensing is an entrepreneurial activity—whether conducted by a new or an existing firm—that involves the identification and conceptualization of opportunities both within and beyond prevailing technological paradigms (Teece, 2008). It involves cognition. As markets evolve, changes in consumer needs, product technologies, and the competitive positioning of other companies can threaten a firm's existing position or open the possibility of a new or better one. In some cases, as stressed by Kirzner (1973), the entrepreneur/manager may have differential access to existing information relative to rivals. More often, sensing opportunities involves scanning, interpretation, and learning across technologies and markets, both "local" and "distant", that are also visible to rival firms (March and Simon, 1958; Nelson and Winter, 1982).

In reality, management teams often find it difficult to look beyond a narrow search horizon tied to established competences. Henderson (1994) cites General Motors, Digital Equipment, and IBM as companies that faced major problems from becoming trapped in their deeply ingrained assumptions, information filters, and problem solving strategies.

Seizing an opportunity requires investments in development via further creative and/or combinatorial activity that addresses the opportunity with new products, processes, or services. It may involve building a necessary new competence or identifying an appropriate external alliance that can secure access to one.

As the global sources of invention and innovation become dispersed, it is less likely that the enterprise can rely on internal R&D, even in very large firms. As a result, services and intangibles that formerly needed to be built internally are outsourced, at least partially. Declines in the cost of computing and communications have facilitated collaboration with suppliers and other elements of the innovation ecosystem (Teece, 1989). This means that markets open up for at least some items of know-how and intellectual property. The expansion of outsourcing has increased the viability of an "open innovation" approach (Chesbrough, 2006). With open innovation, a firm identifies and exploits new technologies and creative capacities developed both inside and outside the boundaries of the firm.[17]

An open innovation approach can even be used to leverage assets that were not previously organized for the purpose. The movie rental firm Netflix, for example, ran a 3-year contest for improving the accuracy of its movie recommendation algorithm by more than 10%, with the winner retaining ownership of the solution, apart from a compulsory free license to Netflix. Over 51,000 contestants

[16] The literature on cumulative innovation, with its emphasis on optimal patent policies (e.g., Scotchmer 1991), captures some of the larger context for innovation, as does that on learning from customers (e.g., von Hippel, 1998). Section 3, above, discusses the broader range of factors that shape innovation.

[17] Open innovation does not necessarily mean that property rights are not sought, protected, and respected.

from 186 countries stepped up to the challenge. The $1 million prize was awarded in September 2009 to a team that had come together for the purpose, and Netflix promptly launched a follow-on competition (Ortutay, 2009). Netflix is not unique. A start-up, Innocentive.com, is a clearing house for this "crowdsourcing" approach where companies can post a research problem along with the amount they are willing to pay for a solution. By mid-2009, it had awarded more than $4 million for over 500 solutions.[18]

Transformation of the firm itself is the third capability required for creating (and capturing) value. Past efforts at sensing and seizing delineate a path for the creation of value, but over time the firm still needs to periodically consider (and reconsider) its own "fit" to the opportunities it plans to exploit. Management must assess the coherence of the firm's business model, asset structure, and organizational routines with respect to its environment. Yet commitment to existing processes, assets, and problem definitions makes this extremely hard to do, especially in a firm that is currently performing satisfactorily.

Organizational innovation can allow the firm to escape unfavorable path dependencies. However, reconfiguring the firm is often costly in terms of both money and morale. When such innovation is incremental, routines and structures can probably be adapted gradually. Radical organizational innovation can potentially be accommodated by a "break out" unit where new capabilities are established before being introduced to the firm as a whole (Teece, 2000).

Organizational innovation has a long history. As Chandler (1962, 1977) and Williamson (1975, 1981) have chronicled, the large, multidivisional (M-form) organization has its roots in the development of line-management hierarchies by the nineteenth-century railroads, which needed a system to manage a continent-spanning organization[19]. In the twentieth century, large corporations such as DuPont and General Motors gradually shifted from a functionally organized (U-form) structure to a multidivisional structure (M-form) that relieved top management of responsibility for operational details. Related innovations such as the conglomerate and the multinational forms allowed organizations to span a wider array of activities and locations than ever before.

Organizational innovation and change continue, with the benefits of greater decentralization being "rediscovered" as the enterprise grows. John Chambers, the CEO of US network equipment company Cisco Systems, described how the management structure of Cisco changed some 15 years after its founding: "In 2001, we were like most high-tech companies—all decisions came to the top 10 people in the company, and we drove things back down from there" (McGirt, 2008). It seems that Cisco now has a more decentralized and collaborative management system, with a network of councils and boards entrusted and empowered to launch new businesses, and incentives to encourage executives to work together flexibly. Chambers claim that "these boards and councils have been able to innovate with tremendous speed. Fifteen minutes and one week to get a [business] plan that used to take six months" (ibid).

Organizational innovation is not only an important form of creating value but of capturing it as well. Armour and Teece (1978) showed that the petroleum industry firms that first adopted M-form structures retained a profit advantage until the innovation was eventually replicated throughout the industry by the early 1970s.

[18] Information from http://www.innocentive.com/crowd-sourcing-news/innocentive-at-a-glance/. Accessed October 8, 2009.

[19] For treatments of organizational innovation and its diffusion, see Armour and Teece (1978), Teece (1980), and the discussion below.

5.4. Capturing value (profiting) from innovation

Companies that are narrowly focused on creating value will not perform well commercially. Invention without a commercialization strategy and access on competitive terms to complementary assets is unlikely to lead to commercial success. Although it is possible to disseminate some innovations (e.g., software over the Internet) without using complementary assets, most industrial innovations are of no benefit to consumers unless considerable resources and complementary assets are mobilized for production, distribution, and promotion. Many engineering-driven companies' brilliant ideas have never found (or created) a market.

Value capture requires selecting the right timing for market entry. In some cases, it is beneficial to be a first mover while in others it may be more advantageous to exploit a gap left by a pioneer. "Seizing" is the core competence cluster for capturing value and is encompassed by the Profiting from Innovation (PFI) framework, which is discussed below. Successful strategies to capture value require choosing an appropriate mechanism for the protection of intellectual property (e.g., trade secrets vs. patents), deciding which activities must be performed by the firm or procured in the market—discussed in Section 7.3—and crafting a business model.

A business model (Chesbrough and Rosenbloom, 2002; Teece, forthcoming) defines a product's value proposition for customers and how the firm will convert that to profit.[20] A business model defines an organizational and financial architecture which embraces and integrates in a consistent fashion (1) the feature set of the product or service; (2) the benefit (value proposition) from consuming/using the product or service; (3) the market segments to be targeted; (4) the "design" of revenue streams and cost structure; (5) the way products/services are to be combined and offered to the customer; and (6) the mechanisms by which value is to be captured.[21]

Google, developer of the leading Internet search engine, founded in 1998, provides clear examples of these business model elements in action. Initially, the company's investments in proprietary search algorithms and computing resources made it the most popular search engine on the Internet, but these innovations did not translate directly to profits. In late 2000, the company began auctioning ads linked to specific keywords (a system similar to that already employed by a competing search site, GoTo.com). Google recognized that part of its appeal was the minimalist design of its web site, and it has limited ads on the site. It was Google's combination of innovation, awareness of how it provided value both to search users and to advertisers, and a system for turning the advertising into revenue—and then into profit—that provided the foundation for the company's ongoing success.

[20] An e-mail from Bill Gates that became public during the Oracle-PeopleSoft merger provides insight into Microsoft's business model for software. In a 2002 message to Microsoft managers, he wrote:
"A product with high share generates a common sense around it.
A common sense that Community Colleges train on that product.
A common sense that temporary workers know the product.
A common sense that certification in the product is a valuable thing.
A common sense that the industry can exchange data or aggregate data using schema specific to that product.
A common sense that someone doing something new should move to that product.
A common sense in terms of how the press covers the product and its development..."

[21] Economics has for the most part not investigated business models. Some specific cases have been analyzed, especially the "bundling" or "tying" of goods for joint sale, typically discussed in an antitrust context (e.g., Adams and Yellen, 1976), and the provision of public goods (e.g., Demsetz, 1970).

To seize the opportunities created by innovation, innovators must excel at understanding not only customer needs, but also the possible future evolution of technology, costs, and customer willingness to pay. Even a successful business model, however, is insufficient to assure sustained profitability when imitation is easy. When hard to imitate—or if used to pioneer a winner-take-all market—a business model can be a source of sustained profitability.[22]

The business model also encompasses a firm's strategy toward its rivals. Positioning within fast-moving industries often takes the form of a standards competition, either in the market (e.g., Windows vs. Mac) or through political maneuvering within a cooperative organization (e.g., the International Organization for Standardization).[23] Control of a successful standard has numerous potential benefits, including licensing revenue, privileged access to new technologies, and influence over technology trajectory.

Seizing and transforming capabilities allow firms to refine and expand their business models in order to exploit new opportunities or defend against new competitive threats. They are the means by which organizations remake parts of themselves, possibly redrawing the firm's boundaries to respond to changes in the business environment. A reformulation of the business model may require radical shifts in the supply chain, asset ownership, or sales channels to ensure continued/improved value capture.

In fast-moving market and technology environments, firms must be ready to continuously reinvent themselves. Netflix, introduced above, is a good example of a firm that has gone through multiple business models in a short period of time (Teece, forthcoming). The company launched an online rental service in 1998, when video rental stores were the standard outlet for home viewing. At its initial launch, the Netflix business model was based on a pay-per-rental service with customers selecting the rentals online and Netflix shipping the movies directly to their homes. By 1999, it was clear to management that Netflix was failing. Later that year, the company launched a monthly fee plan that was subsequently amended to enable subscribers to rent any number of DVDs per month subject to a limitation on the number of DVDs that could be out at any one time, which led to tremendous growth. However, the CEO, Reed Hastings, recognized the potential that streaming media over the Internet had to undermine the company. After several false starts, he began a streaming service over multiple devices already in the home including Xbox 360 game consoles and Tivo digital video recorders. The service is finding acceptance with consumers, but Netflix has yet to work out licensing deals with the movie studios to offer its full catalog online (Roth, 2009). In the meantime, Netflix's national network of dozens of distribution centers—key to rapid delivery of DVDs via the mail—is leased, not owned, permitting the company to remain flexible for the future.

5.5. The profiting from innovation framework

Over the past two decades, our understanding of value capture from innovation and the link to firm strategy has expanded dramatically. A stream of research has stressed the importance of the architecture of the enterprise (especially the boundaries of its ownership and its control of complementary assets)

[22] Markets that can produce winner-take-all outcomes include those in which network externalities (Katz and Shapiro, 1986), switching costs (Klemperer, 1987), or learning economies (Krugman, 1987) confer a substantial incumbent advantage.

[23] David and Greenstein (1990) provide a review of the extensive literature on the economics and competitive consequences of compatibility standards.

for improving the chances of sustainable success when new technologies are commercialized. The role of supporting institutions and public policy—especially appropriability regimes—has also been highlighted.

This body of work has come to be known as the PFI framework[24] and was the topic of a special issue of Research Policy in 2006 (vol. 35, no. 8). PFI addressed a puzzle that had not been well explained in the previous literature, namely: why do highly creative, pioneering firms often fail to capture the economic returns from innovation? The original framework (Teece, 1986) cites several examples (e.g., EMI in CAT scanners, Bowmar in calculators), and the phenomenon does indeed endure. The first-generation PC manufacturers all but disappeared from the scene (and even IBM, which pioneered the Microsoft-Intel PC architecture, exited the business in 2005 by selling its PC business to a Chinese company, Lenovo). Xerox (PARC) and Apple invented the graphical user interface, but Microsoft Windows dominates the PC market with its follow-on graphical user interface. Netscape invented the browser, but Microsoft captured more of the market. Apple's iPod was not the first MP3 player, but it has a commanding position in the category today. Merck was a pioneer in cholesterol-lowering drugs (Zocor), but Pfizer, a late entrant, secured a superior market position with Lipitor.

At first glance, it is tempting to say that these examples reflect the result of Schumpeterian gales of creative destruction where winners are constantly challenged and overturned by entrants.[25] Indeed, entrants with potentially disruptive innovations are almost always waiting in the wings, but many of the cited cases involved mostly incremental/imitative entrants rather than the radical breakthroughs typically invoked in accounts of Schumpeterian competition.

More importantly, there is ample variance in the outcomes from entry, with many cases where first or early movers captured and sustained significant competitive advantage over time. Genentech was a pioneer in using biotechnology to discover and develop drugs, and 30 years later was the second largest biotechnology firm (and, the most productive in its use of research and development dollars) right up to its acquisition by Hoffmann-La Roche in 2009. Intel invented the microprocessor and still has a leading market position more than 30 years later. Dell pioneered a new distribution system for personal computers and, despite recent challenges and many would-be imitators, remained the leader until it was bypassed by Hewlett-Packard in 2007. Toyota's much studied "Toyota Production System" has provided the auto maker a source of competitive advantage for decades despite numerous and sustained attempts at imitation, with the company finally becoming the world's biggest car manufacturer in 2008.

The PFI framework provides an explanation as to why some innovators profit from innovation while others lose out—often to rank imitators—and why it is not inevitable that the pioneers will lose.

The fundamental imperative for profiting from an innovation is that unless the inventor/innovator enjoys strong natural protection against imitation and/or strong intellectual property protection, then the

[24] The core paper in the Profiting from Innovation (PFI) framework is Teece (1986). The intellectual origins of the framework can be traced to Williamson (for his work on contracting), Abernathy and Utterback (for their work on the innovation life cycle), to economic historians like Nathan Rosenberg and Alfred Chandler (for their work on complementary technologies), to Nelson and Winter (for their work on the nature of knowledge), and to Schumpeter (for his focus on the need for value capture). See Winter (2006) for a review of PFI's intellectual origins.

[25] There is a long literature on the role of new entrants in dislodging established firms. See, for instance, Anderson and Tushman (1990), Clark (1985), Henderson and Clark (1990), and Christensen (1997).

potential future stream of income is at risk. The relevant appropriability regime is thus critical to shaping the possible outcomes.

Appropriability regimes can be "weak" (innovations are difficult to protect because they can be easily codified and legal protection of intellectual property is ineffective) and "strong" (innovations are easy to protect because knowledge about them is tacit and/or they are well protected legally). Regimes differ across fields of endeavor, not just across industries or countries.

The degree to which knowledge about an innovation is tacit or easily codified also affects the ease of imitation, and hence appropriability. The tacitness of knowledge varies to some extent over the product cycle. New products and processes are often highly nuanced. Thus in the preparadigmatic phase of technological innovation (Abernathy and Utterback, 1978; Teece, 1986), the tacit component is likely to be high. Once a dominant design emerges, the rate of change of product design slows, and there is then the opportunity, if not the need, to codify technology. However, more rapid rates of innovation mean that there may be no time to codify (make explicit) new knowledge even when it is technically feasible to do so.

Patents can in some cases be used to slow rivals and generate profits. However, patents rarely, if ever, confer strong appropriability, outside of special cases such as new drugs, chemical products, and rather simple mechanical inventions (Levin et al., 1987). Many patents can be "invented around" at modest costs (Mansfield, 1985; Mansfield et al., 1981).[26] They are especially ineffective at protecting process innovation. Often patents provide little protection because the legal and financial requirements for upholding their validity or for proving their infringement are high, or because, in many countries, law enforcement for intellectual property is weak or nonexistent.

The inventor of a core technology can also seek complementary patents on new features and/or manufacturing processes, and possibly on designs. The way the claims in the patent are written also matters. Of course, the more fundamental the invention, the better the chances that a broad patent will be granted, and granted in multiple jurisdictions around the world.

While a patent is presumed to be valid in many jurisdictions, validity is never firmly established until a patent has been upheld in court. A patent is merely a passport to another journey down the road to enforcement and possible licensing fees. The best patents are those that are broad in scope, have already been upheld in court, and cover a technology essential to the manufacture and scale of products in high demand.

In some industries, particularly where the innovation is embedded in processes, trade secrets are a viable alternative to patents. Trade secret protection is possible, however, only if a firm can put its product before the public and still keep the underlying technology secret. Many industrial processes, including semiconductor fabrication, are of this kind.

The conundrum that managers confront beyond protecting the innovation itself is at least twofold. Firstly, most innovations require complementary products, technologies, and services to produce value in consumption. Hardware requires software (and vice versa); operating systems require applications (and vice versa); digital music players require digital music and ways of distributing digital music (and

[26] Mansfield et al. (1981) found that about 60% of the patented innovations in their sample were imitated within 4 years. In a later study, Mansfield (1985) found that information concerning product and process development decisions was generally in the hands of at least several rivals within 12–18 months, on average, after that decision is made. Process development decisions tend to leak out more than product development decisions in practically all industries, but the difference on average was found to be less than 6 months.

vice versa); mobile phones need mobile phone networks (and vice versa); web browsers and web search engines require web content (and vice versa); airlines require airports (and vice versa). In short, technology must be embedded in a system to yield value to the user/consumer. Value capture becomes more difficult if other entities control required elements of the system.

Secondly, the delivery of product/process innovation requires the employment not just of complements but of many inputs/components up and down the vertical chain of production. Hence, when the inventor/innovator is not already in control of the necessary inputs/components, the profitability of the inventor/innovator will be considerably compromised by whatever economic muscle is possessed by owners of required inputs/components. The firm must be prepared to change its assessment over time as the identity of the bottleneck asset may change due to innovation elsewhere in the system. The implications of these complementary asset and value chain considerations for the boundaries of the firm are addressed below in Section 7.3.

An obvious implication of this framework is that the firm's endowment of expert talent (literati and numerati), however brilliant, does not by itself guarantee that the organization will capture much of the value from innovation. Absent quality entrepreneurial managers, good intellectual property protection, some control over complementary assets, an appealing value proposition to the customer, and a good business model, superb performances by literati, numerati, and other employees are likely to be in vain.

6. Innovation and internal structure/management

As discussed above, dynamic capabilities are underpinned by organizational competences, which in turn are underpinned by human resources and other assets. This section considers the nature and management of the firm's key personnel—especially its highly trained specialized talent—and their impact on performance.

6.1. General considerations

The question arises as to how the (strategic) management of human resources can support competences and dynamic capabilities, and thereby assist in building and maintaining a sustained profit advantage.[27] Becker and Huselid (2006) note that the most pressing theoretical challenge facing the strategic management of human resources is the unpacking of a "black box," specifically, that which describes the logic linking the firm's human resources architecture and its performance (p. 899).

The dynamic capabilities framework can help illuminate the causal links between human resources and economic performance. Before outlining this approach further, some general observations are in order.

The first observation is that the stock of human capital readily available to the firm (i.e., its employees and affiliates) cannot meaningfully be thought of as a dynamic capability itself. Dynamic capabilities are organizational. An organizational capability does not stem from the mere presence on the payroll of

[27] Raymond Miles (2007) notes that US scholars were among the early leaders in studying and describing effective managerial and organizational approaches to knowledge creation, sharing, and utilization. However, practice in the field has fallen short of the theory outlined in the textbooks. Miles goes on to give a remarkably good overview of basic management issues.

talented individuals; rather, it derives from ways in which competences are combined and employees interact in productive combinations.

A second observation is that the manner in which human resources need to be managed is task-specific. The three clusters of competences and adjustment mechanisms identified in the dynamic capabilities framework—sensing, seizing, and transforming—require somewhat different human resource management practices. Moreover, sensing, seizing, and transforming are not necessarily sequential; they are likely to be taking place simultaneously across the enterprise, especially if it is multidivisional/multiproduct. In an enterprise with dynamic capabilities, selecting the relevant human resource management practices and procedures is likely to itself be a demanding task.

The next section introduces the experts who help devise and execute the firm's strategy: the numerati and the literati. Entrepreneurs are involved, too. Subsequent sections consider the management of top talent and appropriate incentive systems. The literati and numerati are unlikely to be productive and satisfied in a traditional hierarchical organization, being compensated in traditional ways, and having compensation put at risk for events beyond their control.

6.2. Literati, numerati, and entrepreneurs

There are three categories of talent required for innovation: the literati, the numerati, and entrepreneurial managers. The first two are closely related. The literati and the numerati are the highly educated "classes" of specialists. The literati tend to have both undergraduate and, usually, graduate education in arts and sciences, economics, business, or law. The numerati are likewise highly educated, with capabilities in mathematics or statistics, information systems, computer science, engineering, or accounting and finance. Both groups synthesize and analyze, but the former tend to be more specialized at synthesis and the communication of ideas. The latter excel at analysis, especially of large data sets. Both groups of expert talent are important to today's knowledge economies.[28] Both groups earn top quartile salaries.

The third category is entrepreneurial managers. As Baumol and Strom (2007) note. . ."A close look at the extraordinary economic growth of the last two centuries, however, suggests that the market mechanism does not do its work without the input of individual actors—the entrepreneurs who bring cutting edge innovation to market" (p. 233). Indeed, in fast-paced, globally competitive environments, consumer needs, technological opportunities, and competitor activity are constantly in a state of flux. Opportunities open up for both newcomers and incumbents, putting the profit streams of incumbent enterprises at risk. As discussed in Teece et al. (1997), the path ahead for some emerging marketplace trajectories is easily recognized. In microelectronics this might include miniaturization, greater chip density, and compression and digitization in information and communication technology. However, most emerging trajectories are hard to discern. For instance, when will 3D flat screen technology emerge? Will it be first on small panels, or on large-panel public display monitors? Sensing (and shaping) new opportunities are very much a scanning, learning, creative, and interpretive activity at

[28] In many cases, firms need to tap the skills of numerati and literati externally, via strategic alliances and other knowledge networks, often with formal contracts to spell out specific details about the types of interaction and knowledge sharing that will take place (Mayer and Teece, 2008). However, this section restricts its attention to the expert talent over whom a firm's managers exercise direct authority.

which, by definition, entrepreneurs excel. Investment in research and the related activities that require expert talent is a necessary complement to this activity.

Kirzner (1979) and Shane (2003) analyze entrepreneurship as a process of discovering opportunities. While this is one component of entrepreneurship, as already noted, entrepreneurship is not just a search for opportunities. It is also about the proactive creation of them (through research and development), the accurate assessment of them, and the mobilization of resources to address them.

The work of the entrepreneur (or entrepreneurial manager) includes organizing resources to explore and develop those opportunities, and forming a team with the requisite complementary skills to develop and execute a business model. Understanding just how the various inputs in a creative exercise are likely to respond and coevolve together is decidedly complex. The economic function involves direction setting (strategy) and coordination. Performing this well is likely to involve deep understandings of market opportunities and the technical, physical, and human constraints of the resources at hand.

The most challenging human resources to be managed here are the numerati and literati, who have become an even more important resource to the business enterprise in recent decades (Reich, 2002). Firms must pay great attention to understanding how best to attract, retain, and motivate their most productive literati and numerati. Studies show that the most productive and eminent scientists are strongly motivated. Almost all have good stamina in the sense that they work hard in the pursuit of long-run goals (Fox, 1983, p. 287).[29] Creative activity involving such expert talent is necessary to design and develop new products, services, and business models. Creativity is a difficult process to manage, as it cannot be forced. Creative people may need some direction, but they cannot be micromanaged. As Gil and Spiller (2007) note, "high-level creative activity can only be fostered, it cannot be coerced" (p. 244). This is as true for research and development activity as it is for the arts.

However, because it is difficult to monitor and measure the output of creative individuals, there are also hazards for an enterprise, or any money source that is financing creative activity. Gil and Spiller refer to one class of these as dynamic hazards. The creative individual can potentially have good ideas/breakthroughs and leave the organization where these ideas were developed in order to commercialize them in a context where it may not be necessary to share the rewards with the previous capital provider. Gil and Spiller point out that these are "transaction hazards quite different from the standard transaction cost framework" (p. 245). The fundamental organizational "problem" associated with managing creative activity stems from the nature of creative work: high uncertainty and informational asymmetries (Caves, 2000). The problem is not relieved by internalization, as is the case with many high transaction cost situations (Coase, 1937; Tadelis, 2007; Williamson, 1975, 1985).

6.3. Teams

Although the internal structure of the organization appears to matter for innovation, it has been neglected in much economic analysis. In particular, there is little if any attention to organization design issues as they relate to promoting creativity and inventiveness.

[29] Empirical studies on scientists and engineers suggest that high performers are absorbed, involved, and strongly identified with their work. They also have a preoccupation with ideas, not people. Early in their lives, they show autonomy, independence, and self-sufficiency. They are self-motivated. To maintain their productivity, they do not generally require other people to approve their work.

If firms are to cut time-to-market for new products and processes, cross-functional interaction must take place concurrently, rather than sequentially. Cross-functional teams and cross-departmental networks must be instituted without causing information overload. If such activity becomes too unstructured, it augments rather than displaces bureaucracy. Cross-functional teams should have well-defined goals, subject to redefinition as needed, and draw on the requisite knowledge wherever it may be located.

Teams have become increasingly important to science and engineering tasks because of increased specialization and a corresponding need to integrate individual capabilities. While the numerati and literati value professional autonomy, they are nevertheless willing to collaborate when they perceive that collaboration will yield benefits. Even in the days of Thomas Edison, the use of multidisciplinary research teams was important to the solution of complex technological problems.[30]

Because it is very hard to measure both the inputs and outputs of team members, managers often seek to build a high commitment culture to help effectuate the necessary activity (Baron and Kreps, 1999). In fact, employee motivation appears to be more important than raw competence for outcomes (Katz, 2004).

With expert teams, the identity of the team leader/captain is likely to be of considerable importance. For all to succeed there must be mutual respect between and among experts and leaders.

The very notion of what constitutes a team may be different for creative tasks than for routine operations. When team requirements are too heavy, decision cycles lengthen, expenses mount, and the organization adopts an inward focus. Nelson (1962) notes that team structure in the development of the transistor was broadly inclusive: "several people outside the team also interacted in an important way... teamwork... did not mean a closely directed project" (p. 578).

Teams need not emphasize consensus and compromise, which tend to endorse the status quo. Innovation is often ill served by consensus-driven structures, as the new and the radical will almost always appear threatening to some constituents. Rather, the aim of expert teams should be to achieve excellence while giving some degree of liberty to individualism. Certain especially creative and exceptionally talented individuals can be given special recognition. Hence, team building with top talent is somewhat different from certain aspect of everyday team building. Table 2 summarizes some of the differences between traditional teams and such "virtuoso teams" (Fischer and Boynton, 2005).

A key feature of expert-led teams is that they are likely to be quite fluid. Indeed, not everything is appropriately organized in teams. Rather, groups need to form, get their work done, and disband or move onto other project teams. It is desirable to keep project teams small.

Put differently, one cannot simply assume that more is better when it comes to collaboration. Consensus and participatory leadership is not always a good thing, particularly when the issues are complex and there is considerable asymmetry in the distribution of talents on the team. The right voices need to be heard. Unproductive collaboration can sometimes be more dangerous than missed opportunities for collaboration.

[30] "Treated in many accounts of his life as an inspired, lone inventor, Edison was in fact a research and development manager... At its height, the Menlo Park laboratory had a total of some 40 employees, ranging from glassblowers and machinists to physicists and chemists" (Hounshell and Smith, 1988, pp. 2–3).

Table 2
Key differences between traditional teams and virtuoso teams

Team characteristics	Traditional teams	Virtuoso teams
Membership	Members chosen based on who has available time	Members chosen based on expertise
Culture	Collective	Collective and individual
Focus	Tight project management. "On time" and "on budget" more important than content	Ideas, understanding, and breakthrough thinking emphasized
Clients	Mundane	Sophisticated
Intensity	High/medium	High
Stakes	Low/medium	High

Source: Drawn from Fischer and Boynton (2005).

6.4. Hierarchy

The methods of (light touch) management appropriate to the literati and numerati involve a break with classical notions of the employment relation.

In Coase (1937), the employment relation was defined as one of authority, in which individual employees "agree to obey the directions of an entrepreneur within certain limits" (p. 391). If the relationship is less expensive than hiring the same skills via the price system, then this provides the rationale for internal organization. However, the Coasian conception does not extend to *how* the authority should be exerted.

Alchian and Demsetz's (1972) analysis of the employment relation was different and is in some ways more relevant to innovative organizations. Their claim is that the *raison d'etre* of the firm is team production. According to them, managers do not have any power of fiat or authority that the marketplace does not have. Managers monitoring team behavior detect shirking, and align reward to performance. There is no need in their model for the employee to surrender control, as was assumed in the Coase (and the Simon, 1951) model of the employment relationship. The existence of the firm flows from its ability to enable cooperative activity (i.e., the assessment and effectuation of combinations of employees to achieve goals) superior to that available in a market setting. But it does not follow that the manager has authority over employees beyond that which it exercises over external contractors.

Although Alchian and Demsetz identify team activity as the justification of the employment relationship, their development does not describe the nature of team activity well, particularly for the management of expert teams. The advantage to doing creative work in an internal setting is not just the ability to effectuate cooperation better than the market but also the ability of the firm to (1) organize financial resources thereby insulating top talent from the need to raise money themselves, (2) shape and maintain high commitment cultures to "regulate" teaming, and (3) build the team (identify the needed skills, choose suitable candidates, and provide parameters within which the team will function).

The numerati and literati value autonomy, so traditional command-and-control structures are unlikely to elicit their best performance. Their autonomy is also congruent with optimal resource allocation

because of management's limited information processing bandwidth. In this regard, Nelson (1962) studied the development of the transistor at Bell Labs and noted:

> *"... the type of interaction we have noted in the transistor project requires that individuals be free to help each other as they see fit. If all allocation decisions were made by a centrally situated executive, the changing allocation of research effort called for as perceived alternatives and knowledge change would place an impossible information processing and decision making burden on top management. Clearly the research scientists must be given a great deal of freedom..." (p. 569).*

Strongly authoritarian management that suffocates initiative is anathema. In creative organizations, the evidence shows that management must have a "light" touch, that is, to provide "soft" rather than "hard" direction. Otherwise potentially fruitful combinations of expert talents may be suppressed and creativity will be compromised. Difficult and granular technical tradeoffs and judgments that are needed for problem solving must be made by "front line" professionals themselves and can rarely be sensibly ascertained and then imposed by management.

Accordingly, for innovation to occur, management usually needs to be decentralized/distributed and take the supporting role. Traditional notions of management relying heavily on authority and decisions driven from the center are unlikely to work well in organizations that are highly innovative. Reliance on hierarchy becomes more useful in execution phases of a project, as operations become more routinized or the environment more stable, than in creative phases of innovation and in technological regimes of rapid change (Burns and Stalker, 1961).

As described earlier, Cisco Systems adopted a decentralized structure that appears to have increased its ability to develop and deploy innovations. According to McGirt (2008), Cisco is now "a distributed idea engine where leadership emerges organically, unfettered by a central command" (p. 93). While most efforts are led from below (decentralized or distributed), some are still led from the center. Chambers puts the ratio at 70/30 (p. 135).

The point here is a simple one: in fast-paced complex environments where there is heterogeneity in customer needs, it is very difficult for the firm to be responsive if it has a highly centralized command-and-control structure. Moreover, with a highly talented workforce, excessive centralization can shut down local initiative and creativity. The organizational challenge is to connect individual initiatives to the overall corporate strategy/goals without building an expensive and initiative-sapping hierarchy inside the firm. Every member must act as a responsible decision maker within their professional domain, and there must also be strong leadership in the top management team.

Managing professionals, especially high-level expert professionals, requires rejection of traditional heavy-handed hierarchical structures that may work in more stable industries. Indeed, consistent with the analysis here, Quinn et al. (1996) go so far as to say that it is often necessary to invert the traditional hierarchy in order to create the organizational structures that successful professionals will accept. This is consistent with Teece (2003). With an inverted hierarchy, the job of the manager is to provide support. This proposition overturns some traditional notions of control, if not traditional notions of principal and agent.

In some purely creative environments, it is indeed the highly skilled experts that hire "bosses" rather than the other way around. The Hollywood agency model for creative talent was an early manifestation. As explained by Albert and Bradley (1997), the stars themselves, beginning with Newman, Streisand,

and Poitier, broke away from the studios to create their own production company, First Artists. A key element of First Artists' strategy was to create a climate in which leading actors can control their professional environment and lives. The artists put a professional manager in place, but the manager's mandate was clearly to effectuate the artist's view of how films should be produced. There have been many independent production companies founded since, with varying degrees of success.

University faculties have some similar attributes. The faculty arguably hires their Dean since the Dean generally serves at the sufferance of the faculty, at least in some of the major research universities on the west coast of the United States.

In short, creative and highly skilled knowledge workers, be they scientists, engineers, medical doctors, professors, or economists, desire high autonomy and can be self-motivated and self-directed because of their deep expertise. The university environment caters for this with the tenure system—requiring the discharge of teaching, research, and service obligations by faculty, but allowing the individual faculty member considerable discretion as to whether and when tasks (other than class meetings) are performed.

Expert talent is also likely to be functionally elitist, at least to some small degree. One corollary is that expert talent will be reluctant to accept authority from managers who are not, or have not been, respected professionals themselves. According to Quinn et al. (1996), this is "why most professional firms operate as partnerships and not as hierarchies" (p. 72). Any "power" that individual leaders have should stem from professional and personal respect gained through professional success and through creating and maintaining an open, honest, and transparent culture.

In short, when the modern organization employs many highly skilled individuals, it has to create an organization of colleagues and associates. The W.L. Gore Company, inventor of Goretex, is a well-known case of an innovative organization which has dropped all hierarchical designations. Everyone, including the *de facto* chief executive officer, is an "associate"; the nomenclature of hierarchy has been abandoned.

Implemented properly, the distributed leadership approach is not an abdication of managerial responsibility and good governance. It is just the opposite. The executive leadership team should be responsible to the Board of Directors and to shareholders, as well as to employees and other constituents.

In environments where stimulating creativity is important to enterprise success, management's role is to forge incentive alignment, to expedite resource availability, and to remove barriers standing in the way of professionals doing their work, so long as that work is consistent with the organization's goals. Of course, strong accountability is still required from the literati and the numerati but it can rarely be gained in the traditional manner; figuring out how to achieve this requires new forms of compensation rarely discussed in the literature. Compensation arrangements that recognize differences but reward cooperation must be designed and implemented.

6.5. *Incentive systems*

Reich (2002, p. 107) has observed that talented and ambitious people can earn more today, relative to the median wage, than could talented and ambitious people in the industrial era. Larger and more open or "contestable" markets are the reasons why dispersion in earnings has increased. The higher rewards that top talent can command stems from the value which now seems to flow from creative, analytical, and "rainmaking" abilities of leading professionals. In particular, the skills to help solve complex

problems, to help make critical decisions or resolve complex disputes, and to identify and exploit opportunities command high value.

Intrinsic motivators (e.g., intellectual challenge) are sometimes found to be more important than direct inducements such as compensation for worker performance (Hayton, 2005; Sauermann and Cohen, 2008). Nevertheless, potentially complex compensation issues for expert talent need to be addressed in the context of innovation.

The human resource management literature tends to want to bring uniformity to human resource management practices across the organization. The rationale for this is that (1) employees will judge the system as unfair if disparities in compensation open up and (2) it is more complex to manage an organization if there is variety in human resource management systems and practices. The latter observation may be true, but variety may be unavoidable because building different capabilities requires different systems, and organizations/enterprises usually need to be ambidextrous to create and capture value. In the expert context, pay differentials—even among members of a team—ought not to be an issue so long as they are based on performance and not purely discretionary.

Where financial rewards are directed in ways that are highly subjective, competition takes place to move up the organizational hierarchy. Seniority in the hierarchy allows more personal freedom, control over discretionary resources, and is the confident path to higher compensation. The politics of pay become part of everyday life. People jostle to claim credit, even at the expense of colleagues. A good deal of time and effort is spent posturing in order to appear valuable to the organization, through the eyes of the boss. Eventually the need to do excellent work, much less take risks, gets lost sight of.

Innovation has particular challenges because one must create incentives that promote sensing, seizing, and transforming, and the incentive design likely to aid one might handicap the others. The underlying incentive design problem is even more complicated because the three tasks differ in their measurability and/or timelines. Consider, for instance, sensing and seizing. The first involves highly creative activity with medium- to long-term benefits for the enterprise; the latter, although it also involves creative elements, is more about delivering on the current strategy. The transformational dynamic capabilities, for example, honing the business model, are also highly creative. The metrics for the more creative tasks are necessarily looser than for more traditional executive roles, creating a tension between the need for creative autonomy and the need to offset poor measurement with tighter control.

The better the performance measures available, the less costly it is to provide strong incentives for the activity in isolation. Poor measurement, which might, for example, be caused by unforeseeable external events, means that employees (and employers) face uncontrollable risk which may interfere with respect to achieving rewards. This uncertainty is costly if employees are risk averse.

One approach to the incentive design problem is to simplify the design of the underlying organization by having separate subunits focusing on sensing, on seizing, or on transforming. However, many strategic and organizational contexts will not afford the opportunity for this, nor do all analysts of organization design consider it optimal.[31] More integrated approaches include relying on especially versatile managers with a wide range of capabilities, or on moving executives in and out of particular jobs as the nature of the work changes. However, organizational integration of the three tasks exacerbates the challenge of designing incentives to allow multiple dexterities to flourish in the business

[31] Raisch et al. (2009) provide an overview of the "ambidexterity" literature that debates the degree to which "exploration" and "exploitation" (March, 1991) must be organizationally integrated.

enterprise. Of course, stock options are one vehicle for rewarding multiple activities that jointly create value, so long as those incentive investments are long-term, that is, the options/warrants/restricted stock units have a long vesting period.

Innovating firms face the challenge of finding ways to effectuate cooperation and avoid hierarchical friction. Traditional organizations, when faced with a lack of clear performance metrics, increase rules, directives, and monitoring, which only hampers innovative activity. If firms can indeed provide satisfactory ways of objectively measuring relevant aspects of employee performance, they then can provide greater autonomy by using incentives to begin a virtuous circle of work freedom and high reward.

In this regard, "sensing" (an entrepreneurial activity) is particularly difficult to calibrate. Because of this, it is difficult to start up a new business inside an existing enterprise. It is often easier for those with good sensing skills to become independent entrepreneurs, or to be otherwise associated in the formation of a new business.

Alchian and Demsetz (1972) are rightly skeptical that high-end specialized services can be organized under traditional employment structures because of imperfect monitoring of individual performance. As they put it, "while it is relatively easy to manage or direct the loading of trucks by a team of dock workers when input activity is so highly related in an obvious way to output, it is more difficult to manage and direct a lawyer in the preparation and presentation of a case" (p. 786). Others have suggested the partnership form is the response to this problem, as partners can monitor each other, although this is available in only a limited number of innovation contexts (e.g., consultancies).

As a complement to good incentive design—which is innately difficult to effectuate in the innovation context—managers must inculcate culture/values to bring about greater alignment among the interests and employees. In the organizational behavior literature, such cultures are referred to as "high commitment" cultures. Most are associated with Total Quality Management or Japanese styles of organization (Baron and Kreps, 1999). Elements of high commitment cultures that are relevant to innovation include functional flexibility of employees, systemic approach to solving problems, employee/team empowerment in decisions, and responsiveness to (internal or external) customer needs. Establishing a high commitment culture is a valuable complement to strong incentives. It may also be the low-cost way to proceed.

Table 3 tabulates some of the ways in which traditional firms are likely to be different from dynamically competitive ones with respect to incentives and the management of (expert) human resources.

Table 3
Contrasting views of the business enterprise

Organizational characteristics	Industrial model	Knowledge model (for literati and numerati)
Financial incentives	Base + discretionary bonus salary	Metrics based compensation; limited management discretion
Hierarchy	Deep	Shallow
Leadership	Centralized	Distributed
Work	Segmented	Collaborative
People	Cost	Asset
Basis of control	Authority	Influence and example
Assumptions about individuals	Opportunistic	Honorable

7. Towards a theory of the innovating firm

7.1. Context

As explained above, fundamental changes in the global economy are changing the way firms innovate. More open and competitive trading regimes have increased the importance of know-how and other intangible assets. There are significant implications for the theory of the firm, if such a theory is to connect meaningfully with the contemporary economy.

This section begins by introducing some of the theories of the firm that have emerged outside mainstream economics. Subsequent sections use the dynamic capabilities framework to reconsider the "problems" for which firms are the solution, showing the complementarity of the contracting and capabilities perspectives. The final section argues that a more complete theory of the firm will recognize that firms exist in part to compensate for weak or nonexistent markets for know-how. For the economic system to work, entrepreneurs and managers are required to orchestrate the resources/competences needed for creating and capturing the value of an innovation. Absent managers and management, economic theory cannot explain the evolution and growth of the economy.

One would hope that the theory of the firm would provide some insight into firms as they exist today. Unfortunately, whether one uses the lens of transaction costs (e.g., Coase, 1937; Williamson, 1985), ownership perspectives (e.g., Hart and Moore, 1990), incentive perspectives (e.g., Holmstrom and Milgrom, 1994), or other "modern" theories of the firm, nicely summarized and illustrated by Roberts (2004), the many theories available today still seem to caricature firms, at least those engaged in innovation. Mainstream economics must reconceptualize how markets and market processes relate to the theory of the firm if economic theory is to be both relevant and rigorous.

Furthermore, as Gibbons (2005) has noted, many theories of the firm today can more properly be characterized as theories of the boundaries of the firm. Gibbons further points out, following Cyert and March (1963), that the term "theory of the firm" is more apt for descriptive and prescriptive models of firms' decision making processes. Gibbons provides an excellent survey of four theories of the firm that he calls (1) rent seeking, (2) property rights, (3) incentive systems, and (4) adaptations. He makes oblique reference to the resources/capabilities approaches which he indicates "have mouth watering potential implications" and he "expects them to play key roles in future formal theories of the firm." This section and those that follow are designed to turn some of Gibbons' perceived potential into actuality. The capabilities approach recognizes values in all four streams and incorporates some ideas from each.

To help overcome blatant deficiencies in the standard production–function theory of the firm, transaction cost economics arose. This is now being combined with knowledge-based theories of the firm. Williamson himself sees the "relation between competence and governance as both rival and complementary—more the latter than the former" (1999, p. 406). Knowledge-based theories indirectly respond to the issues raised by Winter (1988), Demsetz (1988), and others. Emanating from the field of strategic management (e.g., Teece, 1982, 1986; Wernerfelt, 1984), these theories show some capacity to inform the theory of the modern firm.

However, theories developed in strategic management do not explicitly endeavor to yield a theory of the (nature of the) firm. Rather, they theorize about how competitive advantage can be developed and maintained, and how supernormal profits can be earned. As discussed above, the resources perspective

indicates how rents can flow, at least for a finite period, from the possession and protection of scarce and difficult-to-imitate assets, or "resources." Nevertheless, resources and capabilities theories can provide insights into the nature of firms, at least those firms that survive in regimes of rapid technological change. Accordingly, they are developed in more detail below.

The dynamic capabilities framework is now well known in the strategic management field. It transcends narrower perspectives and illuminates many issues, including the firm's desirable boundaries. The central concerns of the dynamic capabilities framework—sensing opportunities, seizing them, and transforming firms (and markets) to build and maintain competitive advantage—can provide insights to inform both boundary and decision making issues. Some of these insights are outlined below.

7.2. Dynamic capabilities, cospecialization, and transaction costs

Coase (1937) in his classic article on the nature of the firm described firms and markets as alternative modes of governance, with a profit seeking orientation leading to choices being made so as to minimize transaction costs. The Coasian firm has a simple decision making calculus that supposedly determines the firm's boundaries. The boundaries of the firm are set by bringing transactions into the firms so that the marginal costs of organizing inside the firm are equilibrated with the costs associated with transacting in the market.[32]

A substantial literature has emerged since Coase's landmark 1937 article on the relative efficiencies of firms and markets. This literature, greatly expanded by Nobel Laureate Oliver Williamson (1975, 1985) and others, has come to be known as transaction cost economics. It analyzes the relative efficiencies of governance modes: markets and internal organization, as well as intermediate forms or organization such as strategic alliances.

Contractual difficulties associated with asset specificity are at the heart of the relative efficiency calculations in transaction cost economics. When irreversible investments in specific assets are needed to support efficient production, then the preferred organizational mode is internal organization. Internal organization minimizes exposure to the hazards of opportunistic recontracting and allows more flexible adaptation (Williamson, 1975, 1985).

In some ways, but not in others, the dynamic capabilities approach is consistent with a Coasian perspective. It conceptualizes the firm and markets as alternative modes of governance. However, the selection of what to organize (manage) internally versus via alliances or versus the market depends on the availability and the nontradability of assets, capabilities, and to some extent on what Langlois (1992) has termed "dynamic transaction costs."[33]

The notion of "nontradability" advanced here does not precisely match Coasian or Williamson concepts of "transaction costs." There is nevertheless a strong relationship between specific assets and nontraded or thinly traded assets. However, there are reasons why assets are not traded (or are thinly traded) that do not relate to asset specificity and transaction costs as such. For example, there may simply be no viable business model for licensing certain types of know-how.

[32] Another key feature of the Coasian firm was his emphasis on authority and the employment relationship as the backbones of the enterprise. The discussion on teams and hierarchy in Sections 6.3 and 6.4 implicitly undermine this dimension of the Coasian firm—at least for the innovating firm.

[33] Langlois (1992) defines dynamic transaction costs as "the costs of persuading, negotiating, coordinating and teaching outside suppliers" (p. 113).

Indeed, many companies will simply not license "strategic" technological assets, especially not to direct competitors. The reason, at one level, is because a contract cannot be written that would compensate the licensor for the likely loss of customers if the licensee uses the licensor's technology to compete against the licensor. Theoretically, a licensor ought to be indifferent between own sales and the sales of a licensee if the royalty rate is set to enable royalties to equalize with lost profits. However, such arrangements are rarely, if ever, seen, in part because there is likely to be ambiguity with respect to which customers and what sales are actually lost to the licensee. Accordingly, it is uncommon in the actual world to see exclusive licenses (to direct competitors) when the licensor is able to sell in the same territory. At another level, it may simply be because there are differences in expectations with respect to the profit potential associated with the use of the technology. There are also likely concerns with respect to whether the licensor or the licensee will capture the "learning by using" know-how associated with exploiting the technology. Negotiating, contractually specifying, and monitoring the sharing arrangements are also likely, as Williamson's framework suggests, to be very difficult. [34]

In short, the business model that firms use to capture value from innovation is usually one that involves manufacturing and selling products that contain new knowledge. It is rare that firms will rely entirely on an unbundled business model in which patent/trade secret licensing is used as a mechanism to capture value from know-how. Rambus, Inc, and Dolby Labs are among the exceptions.

In capabilities-based theories of the firm, the concept of cospecialization is particularly important (Teece, 1986). Assets that are cospecialized to each other need to be employed in conjunction with each other, usually inside the firm (Teece, 1980b). Cospecialization and the organizational challenges associated with achieving scope economies and seizing new opportunities is not the emphasis in the pathbreaking scholarship of Ronald Coase, Armen Alchian, Harold Demsetz, or Oliver Williamson. However, it is a phenomenon that requires (theoretical) attention. Some is provided below.

Cospecialized assets are the building blocks of firms. Building and assembling cospecialized assets inside the firm (rather than accessing them through a skein of contracts) is not done primarily to guard against opportunism and recontracting hazards, although in some cases that may be important. Instead, because effective coordination and alignment of assets/resources/competences is important, but difficult to achieve through the price system, special value can accrue to achieving good alignment. This is more easily done inside the firm. Achieving such alignment through internalization goes beyond what Barnard (1938) has suggested as the functions of the executive—which he sees in achieving cooperative adaptation.

The imperative for internalization is not just a matter of minimizing Williamsonian transaction costs. Rather, at least in the dynamic capabilities framework, the distinctive role of the (entrepreneurial) manager is to "orchestrate" cospecialized assets. Performed astutely and proactively, such orchestration can: (1) keep cospecialized assets in value-creating alignment, (2) identify new cospecialized assets to be developed through the investment process, and (3) divest or run down cospecialized assets that no longer yield special value. These goals cannot be readily achieved through contracting mechanisms in

[34] Accordingly, Coca-Cola is unlikely to license its secret formula, and W.L. Gore is unlikely to license the technology behind Gore-Tex fabrics to anyone other than its wholly or partially owned subsidiaries. Intel and TSMC will likewise be reluctant to license their key semiconductor processes to competitors, except with severe restrictions and circumstances of high trust. Brands that signal particular values (e.g., Lexus, Tiffany's) are likewise rarely licensed, partly for contractual reasons, partly for other reasons.

part because of dynamic transaction costs (the costs of negotiating, etc.) but also because there may not be a competent entity to build or "supply" the assets that are needed. In short, capabilities must often be built, they cannot be bought, and there is limited utility in labeling this conundrum as a transactions cost problem.

Rather than stressing opportunism (although opportunism surely exists and must be guarded against), the emphasis in dynamic capabilities is on building specialized assets (that cannot be bought) and on change processes (to keep the enterprise aligned with its business environment). These processes include, research and development, remolding the business architecture, asset selection, and asset orchestration. In dynamic capabilities, "small numbers" bargaining is at the core, as in Williamson (1975). Importantly, the emphasis in dynamic capabilities is not just on protecting value from recontracting hazards; it is also on creating the assets that in transaction cost economics become the object of rent appropriation.

The basic unit of analysis for dynamic capabilities is not the transaction (as in transactions cost economies) but the innovating firm and the (largely intangible) specific assets it creates and controls. To the extent the emphasis in dynamic capabilities is on deals and contracts (explicit or implicit) it is less concerned with avoiding opportunism and more concerned with embracing opportunity. However, there is also considerable emphasis on "production," learning, and innovation. These considerations are largely absent from alternative theories of competitive advantage and from alternative theories of the firm.

7.3. The boundaries of the innovating firm

7.3.1. General

Where a firm draws its boundary is one of the fundamental parameters that a theory of the firm must address.[35] The firm's decision on how to delineate and implement a suitable business model for commercializing innovation and achieving economic rents is another important part of dynamic capabilities. Formulating and implementing a strategy is yet another.

The commoditization of certain services such as back office operations (e.g., testing, telemarketing, benefits management, record keeping, and IT management) has greatly expanded the menu of make-or-buy options facing a firm, and heightens the need to have a theory which can predict the boundaries of innovating firms. The growing range of potential suppliers itself reflects greater global distributions of capabilities. This both expands and complicates the managerial choices of where and by whom activities from managing R&D to after-sales service are to be performed. Moreover, as the dynamic capabilities framework makes clear, this choice must be periodically reevaluated.

Economic theory has so far failed to capture core considerations that are critical to where management decides to draw the boundaries for innovating firms. According to Coase, it is a simple calculus: internalize until the marginal cost of doing so equates with the marginal cost of not doing so. With

[35] A theoretical framework that endeavors to account for the horizontal boundaries of the overall corporation, based on learning, path dependencies, technological opportunities, the selection environment, and the firm's position in complementary assets, can be found in Teece et al. (1994). The firm's ongoing reassessments of its coherence in product space are part of its dynamic capabilities.

Williamson, it is a matter of making sure that internal governance costs are in equilibrium with (asset specificity-driven) transactions costs—other things equal. But other things are often not equal, appropriability issues are likely to be paramount, and internal production costs and other manifestations of capability may depend endogenously on the governance modes chosen.

7.3.2. Capabilities, complementary assets, and intellectual property

The PFI framework introduced in Section 5.4, which builds on the insights from the contracting approach of Coase and Williamson, considers a richer set of factors as relevant to choosing the firm's boundaries. These include intellectual property rights, complementary assets, and time to market considerations. (see also Jacobides et al., 2006). This section will go even further and discuss opportunity preservation, technology pacing, and capability building.

The PFI framework from the beginning considered some factors beyond contracting ones. Teece (2006) summarizes PFI's rules by saying that firms should rely on markets unless there are

> *"compelling reasons to internalize. Such reasons could be grounded in one of two major circumstances: (a) cospecialization, which would lead to transaction costs if heavy reliance was made externally [i.e., on externally provisioned assets/services]; (b) shoring up the appropriability situation by building or buying complementary assets which the innovation would likely drive up in value, or that were otherwise important to getting the job done" (p. 1140).*

The dynamic capabilities framework identifies yet additional factors, most notably whether the firm's competences/complementary assets are sufficiently advanced to enable it to competitively self-supply the required inputs or services. Chandler (1992) noted that during the Second Industrial Revolution the "initial move forward into distribution and marketing by entrepreneurs was that often suppliers and distributors had neither sufficient knowledge of the novel complex products nor the facilities required to handle them efficiently. This is why so many of the new companies met their needs by building almost immediately a national marketing and distribution network staffed by their managers and workers" (p. 87).

The distribution of capabilities is not uniform across firms in an industry.

Nor need suppliers and distributors have the capabilities in place to meet the needs of innovators. Hence, when industries are new, it is often necessary for the developer/manufacturer to integrate upstream/downstream not for transaction cost reasons, but for entrepreneurial and "capability" reasons. That is, there may simply not be an established enterprise with the requisite capabilities able to supply and distribute the innovator's products. Vertical integration upstream and downstream then becomes a necessity, not strictly for transaction cost reasons, but because there simply are not qualified parties available with whom one can contract. [36] As mentioned earlier, capabilities cannot always be bought; they sometimes must be built. Capability considerations help explain the differing interpretations of Oliver Williamson and Alfred Chandler over the backward integration of certain large US companies early in the twentieth century. Chandler (1992) puts it this way:

[36] Once the firm's architecture of supply and distribution had been crafted, its managers must provide the orchestration, or "system integration" function. The prevalence of outsourcing has made this integration function a strategic competence of the first order (Pisano and Teece, 2007; Prencipe et al., 2003).

Williamson (1985, p. 119) notes that:

> *"'Manufacturers appear sometimes to have operated on the mistaken premise that more integration is always preferable to less.' He considers backward integration at Pabst Brewing, Singer Sewing Machine, McCormack(sic) Harvester, and Ford 'from a transaction cost point of view would appear to be mistakes.' But when those companies actually made this investment, the supply network was unable to provide the steady flow of a wide variety of new highly specialized goods essential to assure the cost advantages of scale. As their industries grew and especially as the demand for replacement parts and accessories expanded, so too did the number of suppliers who had acquired the necessary capabilities" (p.89).*

Chandler goes on to note that:

> *"The point is that an understanding of the changing boundaries of the firm required an awareness of the specific capabilities of the firm and the characteristics of the industry and market in which it operates* at the time *the changes were made. Many of the first-movers in the new capital-intensive industries which integrated forward into distribution and marketing and backward into control of supplies did so on an international scale. Knowledge gained in the creation of a wholesaling or direct marketing organization at home led to building a comparable one in foreign markets" (ibid, emphasis in the original).*

Chandler's historical analysis is very consistent with a dynamic capabilities theory. Perhaps his accounts would be better couched in transaction costs terms, but it is not immediately apparent how that would be done.

7.3.3. Opportunity "management"

In economic theory today, the general outsourcing logic relies on Williamsonian considerations of asset availability/specificity and expected contingent moves in prices. For example, when a firm must make a relationship-specific investment in order to work with a supplier, it exposes those nonredeployable assets to subsequent recontracting hazards that can be eliminated by vertical integration (Williamson, 1985). These are important insights, but they need to be supplemented by an understanding of technological and market hazards of a different kind. Also, opportunity needs emphasis alongside opportunism.

In business transactions when new technology is at stake, a less understood set of hazards (and opportunities) may arise.[37] This class of contracting hazards (and opportunities) stems not so much from the extraction of quasi-rents, but from the need to guard future strategic opportunities from certain competitors.

Situations may arise when a vertically integrated firm has the ability to use its upstream technological prowess to deny a downstream rival access to a patent that one must practice in order to engage in certain future technological and commercial opportunities.[38] An innovator's ability to pace, direct, control, and guard the development of new products and technologies poses risks to competitors.

[37] This section is based in part on de Figueiredo and Teece (1996).

[38] This notion can also be viewed as a dynamic extension of the raising rival's cost literature (Salop and Scheffman, 1983). However, the predicament analyzed is unlikely to require antitrust intervention.

Even when firms leave research and development/new product development to nonintegrated suppliers, the downstream firm may then have no choice but to purchase critical components from a supplier who also emerges as a competitor.

A subtler form of hazard is the inability to pace or direct the evolution of new products[39] that depend on a supplier's proprietary technology. If a firm has no input into a supplier's development process, the supplier might be able to independently shape the trajectory of the technology. Transaction cost economics would posit that such hazards can best be understood as contracting issues. However, one can question whether transaction costs and recontracting hazards are the core issues; rather, it is that outsourcing may lead to the loss of opportunities to accumulate critical competences important to the firm's overall new product development strategy. Theoretically, contracts might be written that would require royalty-free grantbacks of any trade secrets accumulated. However, such arrangements are rare.[40] Opportunity management may require investment in own R&D, rather than relying on the efforts of suppliers.

7.3.4. Coordination of complementary assets and systems integration

Another reason that a firm faces hazards when relying on an external supplier for complementary innovation is the difficulty associated with accomplishing coordination of complementary assets and activities. This is related to what Richardson (1960) and Williamson (1975) have called "convergence of expectations." Investment (in research and development) must be coordinated between upstream and downstream entities, and this is difficult to effectuate using contractual mechanisms.

Coordination is of greatest concern when innovation is systemic (Teece, 1988). Systemic innovation requires harmonized action by all parties (e.g., the development of new cameras and film which instant photography required). When there is asymmetry in capabilities between firms, achieving harmonization is difficult. Boeing discovered this to its cost when it decided to rely on a global array of suppliers to develop parts for its new 787 Dreamliner as a cost-sharing measure; some suppliers lacked the capabilities to develop parts of the necessary quality, and Boeing had cut back its monitoring capability. Deficits in the capabilities of suppliers resulted in years of delay (Michaels and Sanders, 2009). It is not clear, from the perspective of theory, whether this is best viewed as a contracting problem or a capabilities issue. However, the latter appears to be more powerful.[41] The Boeing experience echoes Lockheed's experience three decades earlier when the L1011 wide bodied plane was delayed by the failure of Rolls Royce to develop and deliver on time the RB211 jet engine

[39] The software industry provides an illustration of how an integrated firm can pace technological development downstream of its operating system. Microsoft develops its operating systems in-house. It also develops applications while looking to others for additional applications. These independent application designers rely on Windows to run their applications. Thus, Windows acts as a constraint on some of the technological features of the downstream application (e.g., protocols for data exchange). Microsoft's ability to pace the upstream technology and its ability to use its operating system technology in its applications software has helped it to become one of the dominant players in applications.

[40] An exception is Pilkington, which for many years had such terms in its float glass license arrangements.

[41] As a Boeing executive, Jim Albaugh, noted in explaining delays with the Dreamliner: "while Boeing's commercial division had a fine record as a manufacturer, the defense unit had far more experience with the complex development required for an aircraft such as the 787, which has a much larger amount of lighter composite materials than normally used in commercial planes . . . when you only do a development program every decade or so, I think you lose some of those capabilities and some of the knowledge" (Clark, 2009).

for the L1011, effectively putting Lockheed out of the civilian aircraft industry. This was not an exercise of opportunism by Rolls Royce; rather it reflected Rolls Royce lack of ability to achieve ambitious technological goals.

Teece (1996, 2000) and Chesbrough and Teece (1996) have analyzed the difficulties in coordinating the development of complementary technologies when pursued independently and coordinated by contract.[42] Delays are frequent and need not result from strategic manipulation; they may simply flow from uncertainty, limited capabilities, and divergent goals among the parties.[43]

Autonomous innovations, which do not require coordinated activities between parties, can occur within one organization's boundaries and then be "plugged in" to the bigger project. Autonomous innovations are pervasive when standards are present, such as the open architecture of the IBM personal computer.

Outsourcing components used in new products and new systems also raises hazards of technology leakage to competitors. Arrow (1962) first brought to light the disclosure problem in the market for know-how and others have since elaborated on this and related technology transfer problems (Goldberg, 1977; Teece, 1981, 1985, 1986). Appropriability hazards are of concern when property rights are difficult to establish. The leakage can occur vertically (upstream and downstream) as well as horizontally (Silverman, 1996).

Proprietary knowledge that leaks from buyer (supplier) to supplier (buyer) in the course of fulfilling a purchase contract is especially problematic when the supplier (buyer) is integrated downstream (upstream). The argument is of course symmetric. Although an independent supplier who obtains knowledge from the buyer may choose to integrate into the downstream product, the likelihood that this will occur is small. However, a firm which is already vertically integrated downstream and supplies a downstream competitor may be able to take the know-how that has leaked to its upstream division and incorporate it into the downstream products and processes relatively quickly.[44]

In the presence of these hazards, maintaining technological control of the innovation trajectory sometimes requires vertical integration (including heavy investment in R&D). When this is not possible, other strategies for (re)shaping the industry's architecture must be pursued, for example, through corporate venture investments in the supply base to build a competitive market for key complements (Pisano and Teece, 2007).

[42] These dynamic coordination issues are very different from the rent extraction of concern in the economics literature on innovation. In Farrell and Katz (2000), for example, a monopolist may extract so much rent from the firms selling a competitively supplied complement that their innovation is suboptimal even from the monopolist's perspective.

[43] MIPS encountered this with their failed attempt to promote their Advanced Computing Environment (ACE) to compete with Sun's Scalable Processor Architecture (SPARC). MIPS set up alliances with Compaq, DEC, Silicon Graphics, and other firms to pursue a RISC-based computing standard. However, soon after DEC and Compaq announced that they were going to reduce their commitment to ACE, the alliance fell apart because MIPS could not pick up the slack in some of the upstream activities. It failed both to develop competencies in key aspects of the technology and to create a common expectation for the alliance (Gomes-Casseres, 1994).

[44] The term "leakage" does not mean that intellectual property rights have necessarily been violated. This leakage is the quite legal imitation and emulation that take place in the normal course of business.

7.4. The fundamental economic "problems" to be solved by the (innovating) firm

As earlier sections made clear, the fundamental problems solved by the innovating firm are not just coordination to overcome high transaction costs (and other issues flowing from incomplete contracts) but also the design and implementation of opportunity and value capture strategies and mechanisms. These strategies and mechanisms can help solve the appropriability problems and help create the new organizational capabilities needed to address new opportunities as they arise. These theoretical challenges require the joining of transaction cost economics and capabilities theory. The problems associated with creating and capturing value are as important as coordination and incentive design in defining the nature of the (innovating) firm.

Likewise, the economic problem being addressed here has little to do with incentive design and principal-agent problems. Managing expert talent (literati and numerati) has less to do with metering and monitoring to detect and punish *opportunism* than it has to do with detecting, monitoring, and metering *opportunity*.

Alchian, Demsetz, and Williamson have all emphasized opportunistic free riding as one organizing principle. Clearly, it is an important issue. Williamson assumes, correctly so, that human actors are boundedly rational, self-interest seeking, and opportunistic. The dynamic capabilities framework emphasizes other (arguably less ubiquitous and unevenly distributed but nevertheless more salient) traits of human nature: (1) entrepreneurship and pursuit of high-risk/high-reward opportunities, and (2) foresight and acumen.

Williamson (1999a) appears to recognize that skills and foresight are not uniformly distributed. He quotes businessman Rudolf Spreckels—"Whenever I see something badly done, or not done at all, I see an opportunity to make a fortune." Williamson comments: "Those instincts, if widely operative, will influence the practice and ought to influence the theory of economic organization" (p. 1089). This statement invites a capabilities-based theory of the firm.

There are other differences between transaction cost and capabilities perspectives. Williamson makes the transaction the unit of analysis, with (the degree of) asset specificity a key explanatory variable in organizational design. In the dynamic capabilities framework, complementary assets and the degree of their cospecialization are important explanatory variables. The firm is the focus, if not the unit of analysis.

The utility of transaction cost economics and related frameworks for make-buy-ally and related governance decisions are not in dispute. But transaction cost economics leaves us without an understanding of the distinctive role of the manager. Executives must not only choose governance modes (between market arrangements, alliances, and internal organization); they must also understand how to design and implement different governance structures, to coordinate investment activities, to design and implement business models, and to choose appropriability strategies.

A dynamic capabilities/knowledge-based theory of the firm is not completely at odds with Coase, Williamson, Hart, Moore, and others. In the dynamic capabilities framework, opportunism is not held in abeyance, nor are principal-agent and incentive issues ignored. But the essence of the innovating firm lies in the generation, configuration, and leveraging of knowledge assets and organizational capabilities to allow the owners (shareholders) to create and capture value.

While the understanding of the existence and growth of the firm can be assisted by transaction cost theory, the advantages of organizing economic activity inside the firm go well beyond savings in transaction costs, however, these are manifested. Advantages also flow from the ability of entrepreneurial managers to combine idiosyncratic cospecialized assets not just to achieve "scope economies," but to create and capture value by offering distinctive services (solutions) to customers while solving the firm's appropriability problems. Over reliance on the transaction cost economics apparatus can add unnecessary baggage. For instance, if one wanted to understand issues surrounding creating value, not simply protecting value created, transaction costs can only go part of the way. The firm's routines for sensing, seizing, and transforming can provide a basis for profitability well beyond the avoidance of contracting costs and hazards.

There is empirical evidence that even outsourcing decisions do not depend on transaction cost (asset specificity) considerations alone. Studies show that "system effects" such as interdependencies and complementarities (Monteverde and Teece, 1982)[45] and capability advantages (Argyres, 1996) impact economic organization in a statistically significant manner.[46] These studies seem to indicate that boundary placement influences production learning and impacts R&D efficiency (Armour and Teece, 1980), resulting in lower costs and superior innovation potential.

What then is the role of managers in the theory of the innovating firm? They are not primarily micromanaging creative people so as to stamp out opportunistic behavior. Nor are they merely engaged in adaptive sequential decision making. Rather, they are helping the organization to create and implement the systems and structures that enable the firm to sense opportunities, execute on them, and transform as the environment changes, which inevitably it will.

Opportunism is controlled not just through metrics and monitoring, but also through high commitment cultures/values. Innovative firms typically need strong values because it is harder in the loosely structured internal environments that innovation requires to define and measure performance and implement rigid controls. Incentive issues are powerful as well; creative and entrepreneurial activity need to be encouraged and rewarded.

The transaction cost economics perspective clearly needs dynamic capabilities, and vice versa. The complementarity between capabilities-based views and contractual/transaction costs/property rights views is hopefully apparent. It has been remarked on by this author elsewhere, as well as by others (e.g., Foss, 1996).[47] Transaction cost economics implicitly assumes what might be referred to as capabilities neutrality. In transaction cost economics, so-called "production costs"—which might be thought of as a proxy for the firm's level of (operational) capability—are assumed to be the same across organizational types so that the choice between market and nonmarket arrangements swings entirely on transaction/governance costs. This assumption is a natural connection point to capabilities theory, which clearly indicates that the level of capabilities is itself a function of managerial activity/excellence

[45] This article is often cited as reflecting empirical support for transactions cost economies, which indeed it does. But the variable for systems effects has more explanatory power and is consistent with the capabilities perspective advanced here (see text below).

[46] Monteverde and Teece have been cited most extensively as providing the first empirical support for transaction cost economies. However, a little noticed feature of the econometrics is that systems effects and firm effects are more powerful explanatory variables.

[47] The Profiting from Innovation framework (Teece, 1986) illustrates how a contracting framework is useful as a tool for building a (dynamic) capabilities-based theory of the firm (see also Winter, 2006).

(or lack thereof). Differences in capabilities can lead to wide disparities in "production" costs within an industry. The field of strategic management is built on the recognition that firms are different—not just as to governance, but with respect to other features too (Rumelt et al., 1991)—and that this drives performance differences.

The (dynamic) capabilities framework, which posits that knowledge assets and their (dynamic) management have become central to profit maximization in an era of globalized commerce and information, suggests a new theory of the firm, one that is consistent with the observation of Marshall (1898, p. 213) that "capital consists in a great part in knowledge and organization: and of this some part is private property and the other part is not. Knowledge is our most powerful engine of production—organization aids knowledge." The proposed new capabilities-based theory opens up the black box of the firm and injects into economic theory new considerations which are generally not central to the theory of the firm as commonly presented.

7.5. Recapping complementarities, cospecialization, and the scope of the (innovating) firm

The theory of the innovating firm has benefited, and can benefit further, from a more rigorous exploration of the concepts of complementarities and cospecialization. The earliest use of the idea of complementarities in economics can be traced to Edgeworth (1881). Early applications in the economic development literature include Hirschman (1958) and in the innovation literature can be found in Rosenberg (1979, 1982) and Teece (1986). Work on complementarities in a strategic context includes Teece (1980b), Milgrom and Roberts (1990a,b), and Miller (1988).

Rosenberg (1979) notes: "Time and again in the history of American technology it has happened that the productivity of a given invention has turned on the availability of complementary technologies... these linkages are both numerous and of varying degrees of importance" (pp. 26–27). Furthermore, "the growing productivity of industrial economies is the complex outcome of large numbers of interlocking, mutually reinforcing technologies, the individual components of which are of very limited economic consequences by themselves. The smallest relevant unit of observation, therefore, is seldom a single innovation but, more typically, an interrelated clustering of innovations" (pp. 28–29).

Complementarities exist when various activities reinforce each other in such a manner that performing multiple activities together lowers/(raises) cost, increases economies/(diseconomies) of scope, or otherwise improves/(depresses) payoffs.[48] More technically, complementarities exist when the mixed partial derivatives of a cost function or a payoff function provide positive returns at the margin associated with one variable increasing as the levels of other variables increase too. Doing more of one activity increases the returns from doing more of another. The aggregate economic value achieved by combining two or more complementary factors therefore exceeds the value that would be achieved by applying these factors in isolation.

Of course, as pointed out by Teece (1980b), this in and of itself has no direct implication for the theory of the (boundaries of the) firm, although it has powerful implications for economic organization

[48] The notion of complements has gained mathematical tractability through the concept of supermodularity (Milgrom and Roberts, 1994; Topkis, 1978, 1987). For an excellent review of the literature, see Ennen and Richter (2009). This is discussed below.

more generally. The existence of positive complementarities indicates the advantage of having separate activities occur together. However, without more structure to the concept, one cannot predict where the individual firm boundaries should lie because contractual arrangements exist that, in theory, can enable joint activities to take place absent common ownership of the parts.

While the importance of complementarities is now being recognized, the approach still needs additional specificity (with respect to causal relationships among key constructs) to allow it to morph fully into a falsifiable theory. Put differently, a robust theory of complementarities that provides economic insight is yet to emerge. While there is little doubt that complementary relationships exist among heterogeneous factors inside the firm (and that these can impact firm performance), the contexts in which such interactions occur is yet to be adequately specified. However, some evidence has been assembled. Monteverde and Teece (1982), while testing for the importance of asset specificity in predicting outsourcing decisions for GM and Ford, also found that a "systems effect"—defined as "the degree to which any given component's design affects the performance or [system-level integration] of other components" (p. 210)—was statistically significant in explaining GM and Ford's outsourcing decisions. The longstanding notion of strategic "fit" is obviously consistent with notions of complementarity.

It should be noted that the notion of complementarity can be applied at a high level of aggregation, as with the Toyota System of production. It can also be applied at a high level of specificity, such as the complementarity between the (integrated) design and manufacture of automobile components. An example is the complementarity in design between an automobile's exterior grill and its headlamp assemblies (Monteverde and Teece, 1982). Parmigiani and Mitchell (2009) use the example of automobile dashboards, which they note typically consist of multiple, interrelated, complementary components. Both levels of aggregation seem to provide insights, suggesting the power and generality of insights from the concept of complementarity.

Complementarities expressed through their mathematical corollary (supermodularity) break from classical economics. Most classical economics models of production recognize only traditional "factors of production" like labor and capital and assume homogeneity with respect to the distribution of these factors among firms. The standard production function sees no benefit from the use of particular inputs—in the sense that, apart from diminishing returns related to fixed factors, there is no special significance to the identity of particular factors of production (Teece and Winter, 1984). Moreover, everything is infinitely divisible—indeed, twice differentiable—and firms maximize some objective function subject to constraints. Complementarity does not require divisibility; changes in one variable may require discrete (nonincremental) changes in another.

With production functions of the standard kind, decision makers need only equate marginal revenues to marginal cost and they will deliver global maxima in output. There are serious issues with this theory surrounding the search for, and the discovery of, a global maximum, if one exists. Complementarity modeled as supermodularity enables some departures from this extreme caricature by at least recognizing local maxima. It also accepts that payoff functions may be discontinuous. Design choices are recognized as being discrete and not necessarily continuous. These perspectives have received endorsement by organizational ecologists and strategic management scholars including Levinthal (1997), Porter and Siggelkow (2008), and Teece (2007a).

However, capabilities theory at present runs the risk of providing more *ex post* rationalization than *ex ante* guidance with respect to the particulars of the requirements—with Teece (1986, 2006) being

possible exceptions since these papers are quite explicit about the contexts in which complementary assets are important for capturing value from innovation. These papers are also able to specify when complementary assets should be included inside the boundaries of the enterprise, as discussed in Section 7.3, above.

7.6. The "nature" of the innovating firm

Knowledge-based theories of the firm see business organizations as accumulating capabilities in path-dependent ways. Recognizing, creating, and exploiting complementarities is very much at the core of what firms do. Sustained "abnormal" or "supernormal" profitability occurs because factor markets for certain types of assets (particularly intangibles and idiosyncratic physical and human assets) are not fully efficient. To take full advantage and earn superior profits, firms need to sense, seize, and transform in ways that exploit inefficient factor markets. Indentifying and securing combinations and permutations of assets which enable the enterprise to address customer needs is key.

As firms build the microfoundations needed to sense, seize, and transform, all the while exploiting complementarities, they lay the foundations for sustained above-average profitability. There is nothing in Ronald Coase's or Oliver Williamson's work to explain how firms identify and exploit complementarities and develop competitive advantage. This raises the question of how the Coase/Williamson conceptualizations of the firm relate to dynamic capabilities.

As stated earlier, the knowledge and contracting perspectives are complementary theories/frameworks. No theory of the firm can ignore contractual issues. But neither Coase nor Williamson see a firm as a pure nexus of contracts. Nor do they see the firm as merely "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" (Kogut and Zander, 1992).

There is clearly a way for knowledge-based theories and transaction cost perspectives to be brought together. Arrow (1974) provided a commanding and potentially unifying insight. He observed that the reason firms exist is not simply due to high transaction costs; rather, markets in some situations simply do not work and there is market "failure."[49] One can do a thought experiment and conclude that if the transactions were forced into a market, transaction costs in such circumstances would be very high; but it is perhaps simpler to just recognize that there are many circumstances where internal organization is clearly a necessary and superior way to organize, and it is desirable for innovative activity to take place inside a firm orchestrated by entrepreneurial managers embedded in some kind of management structure.

For purposes of building a theory of the innovating firm, it is important to specify the contexts in which these market failures are prevalent. The most important (and also the most under-researched) domain within which organization inside the firm is likely to be necessary is the creation, transfer, protection (appropriability), and orchestration (so as to exploit complementarities) of know-how and other intangibles. As noted more than two decades ago (Teece, 1981): "unassisted markets are seriously

[49] Arrow (1969) acknowledged that in some cases markets might simply not exist. Williamson (1971), in his best known statement on market failure, which he still endorsed 28 years later Williamson (1999b), restricted his attention to those that were "failures only in the limited sense that they involve transaction costs that can be attenuated by substituting internal organization for market exchange" (p. 114).

faulted as institutional devices for facilitating trading in many kinds of technological and managerial know-how. The imperfections in the market for know-how for the most part can be traced to the nature of the commodity in question" (p. 84). The market is also imperfect as a tool to create know-how. One can "buy in" technology more easily than one can have it created through a contractual agreement and then transfer it in. "Creation" must frequently be done internally, even though external sourcing is usually a necessary complement to own development.

One must recognize that it is only after industrially relevant know-how is first created that it can be traded (via licensing arrangements). Even once its created, mutually beneficial trades frequently do not happen because the property rights covering knowhow may be poorly defined (fuzzy),[50] the asset difficult to transfer, or its use difficult to meter. Internal resource allocation within the firm (a managerially directed activity) is the only viable alternative.

Moreover, because of complementarities and cospecialization, many intangible assets may be more valuable when they can coevolve in a coordinated way with other assets. The ability to assemble unique configurations of cospecialized assets, as in the case of systemic innovation (Teece, 2000), can therefore enhance value. Rosenberg (1979) seems to go further and argues that such coordination and clustering is necessary for value to be created.

In a globalized, knowledge-based economy, firms can secure short-term advantage from the coordination of bundles of difficult-to-trade assets and competencies, at least when such assets are scarce and difficult to imitate. Advantage that is sustainable over a longer term, however, can only flow from unique abilities possessed by business enterprises to continuously shape, reshape, and orchestrate those assets to create new technology, to respond to competition, achieve critical market mass, exploit complementarities, and serve changing customer needs. The particular (nonimitable) orchestration capacity of a business enterprise—its dynamic capabilities—is the irreducible core of the innovating firm. It cannot be reproduced simply by assembling a constellation of contracts.

Fundamentally, business firms know how to do things. Most figure out how to adapt and possibly even shape their environment to some (small) degree. As noted earlier, even Harold Demsetz was willing to see the firm as a repository of knowledge.

However, it is not clear that many economists are willing as yet to recognize the implications of firms being repositories of knowledge and instruments for learning. One exception is Winter (1982) who correctly notes, "it is the firms, not the people who work for the firms, that know how to make gasoline, automobiles, and computers" (p. 76).

Organizational capabilities explain why an enterprise is more than the sum of its parts. They also help explain why the profits of the enterprise cannot be completely competed away in factor markets. Employees can come and go to a certain extent and the organization can continue without interruption.

Mainstream theory too often takes production functions and production sets as given, ignores complementarities and cospecialization, and fails to explain capabilities and heterogeneity among firms even in the same industry. Mainstream theory also completely sidesteps the problem of how firms actually perform the tasks of storing the knowledge that underlies productive competence, transferring it internally (or externally), augmenting it in value-enhancing ways, and identifying and exploiting complementarities.

[50] See Teece (2000) for discussion of the fuzzy boundaries associated with intellectual property rights.

In short, managers often create great value by assembling particular constellations of complementary and cospecialized assets, especially knowledge assets, inside the enterprise to produce highly differentiated and innovative goods and services that customers want. This process of identifying, assembling, and orchestrating constellations of complementary and cospecialized assets is a fundamental function of management—and points to the fundamental "nature" of the innovating firm. It is different from the Coasian firm.

8. Conclusion

This chapter has endeavored to motivate and shape a theory of the innovating firm consistent with descriptions of the firm that business historians like Alfred Chandler have provided. Historians remind us that innovation is central to the role of the enterprise in modern society. Accordingly, a theory of the firm that fails to reflect these dimensions is unlikely to have utility for business strategy and public policy analysis.

The good news is that the theory advanced here does not require one to displace all of mainstream theory. Mainstream approaches can be augmented with now well-established concepts from transaction cost economics, from the economic and organizational theories of complements, and from (dynamic) capabilities theory. Innovation scholars and industrial organization theorists will hopefully demonstrate over the next decade how organization theory, strategic management theory, and innovation theory can inform each other, while also benefiting from the study of business history and industrial organization.

Acknowledgments

I thank Greg Linden for help in content and in editing. Gary Pisano and John de Figueiredo, along with the editors Nate Rosenberg and Bronwyn Hall, also provided helpful insights and comments for which I am much indebted. Ken Arrow, Henry Chesbrough, Giovanni Dosi, Connie Helfat, Dan Lovallo, James March, the late Edwin Mansfield, David Mowery, Richard Nelson, Gary Pisano, Christos Pitelis, Oliver Williamson, Sidney Winter, and many others provided decades of inspiration and ideas.

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